



**Department of Energy**  
**National Nuclear Security Administration**  
Washington DC 20585

November 28, 2016

OFFICE OF THE ADMINISTRATOR

MEMORANDUM FOR NICOLE NELSON-JEAN  
MANAGER  
LIVERMORE FIELD OFFICE

FROM: MADELYN R. CREEDON [REDACTED]  
PRINCIPAL DEPUTY ADMINISTRATOR

SUBJECT: Lawrence Livermore National Security, LLC, DE-AC52-07NA27344,  
Fiscal Year 2016 Award Fee Determination

The National Nuclear Security Administration (NNSA) has completed its assessment of Lawrence Livermore National Security, LLC's (LLNS') effectiveness in meeting the performance expectations established in the Fiscal Year 2016 Performance Evaluation and Measurement Plan for the period of October 1, 2015 through September 30, 2016. Based on assessments provided in the NNSA Performance Evaluation Report, award fee amounts are as follows:

	<u>At Risk</u>	<u>Available</u>	<u>Final</u>	<u>Percent</u>	<u>Award Term</u>
Goal 1: Manage the Nuclear Weapons Mission	35%	\$8,350,735	\$7,682,676	92%	Met
Goal 2: Reduce Global Security Threats Mission	15%	\$3,578,886	\$3,328,364	93%	Met
Goal 3: DOE Strategic Partnership Project Mission Objectives	5%	\$1,192,962	\$1,085,595	91%	Met
Goal 4: Science, Technology & Engineering (ST&E)	10%	\$2,385,924	\$2,218,909	93%	Met
Goal 5: Operations & Infrastructure	25%	\$5,964,811	\$4,235,016	71%	Met
Goal 6: Leadership	10%	\$2,385,924	\$1,932,598	81%	Met
Total		\$23,859,242	\$20,483,158	86%	



In addition, the fixed fee and total fee summaries are provided below for your information:

Fixed Fee	\$10,225,389	\$10,225,389
SPP (Fixed Fee)	\$6,275,000	\$6,275,000
Total Fixed Fee	\$16,500,389	\$16,500,389
<b>Total Summary</b>	<b>\$40,359,631</b>	<b>\$36,983,547</b>



---

National Nuclear Security  
Administration

Lawrence Livermore National  
Security, LLC

Performance Evaluation  
Report (PER)

---

NNSA Livermore Field Office

Evaluation Period:  
October 1, 2015 – September 30,  
2016

---

**November 15, 2016**

---

## Executive Summary

This Performance Evaluation Report (PER) provides the National Nuclear Security Administration (NNSA) assessment of Lawrence Livermore National Security, LLC's (LLNS') performance in managing and operating the Lawrence Livermore National Laboratory (LLNL) under contract DE-AC52-07NA27344 for the period of October 1, 2015 through September 30, 2016, as evaluated against the Goals defined in the Performance Evaluation and Measurement Plan (PEMP). The National Nuclear Security Administration (NNSA) took into consideration all input provided (e.g. Contractor Assurance System (CAS), Program Reviews, etc.) from NNSA Program and Functional Offices both at Headquarters and in the field. NNSA also considered LLNL's self-assessment, which was provided per the terms and conditions of this contract, and is generally in agreement with the information provided in that assessment. The PER includes adjectival ratings per the Federal Acquisition Regulation (FAR) Subpart 16.4, Table 16-1, for each Goal based on LLNL's performance against the Contributing Factors, Site Specific Outcomes, and other criteria as set forth in the Strategic PEMP. The evaluation of performance considers unanticipated barriers (e.g., budget restrictions, rule changes, circumstances outside Contractor's control), accomplishments, and other events. The degree of difficulty is considered when determining whether these outcomes meet or exceed expectations.

Performance against the Goals summarized below, resulted in an overall rating of Very Good for Lawrence Livermore National Security, LLC. Specific observations for each Goal are provided in the following pages.

Goal 1: Manage the Nuclear Weapons Mission was rated as Excellent as LLNL exceeded nearly all expectations, successfully delivering on our nation's challenging stockpile requirements. LLNL continued to lead the Weapons Laboratories in strengthening the underpinning and future of stockpile stewardship. LLNL successfully completed the Defense Programs (DP) level-1 milestone, all DP level-2 milestones (119), and the Getting-the-Job-Done List (GTJDL) items on schedule and within cost. It fully met all commitments for W80-4 Life Extension Program (LEP). LLNL made significant progress in the areas of Advanced Manufacturing, Code Development and modeling capabilities, High Energy Density Physics, the National Ignition Facility (NIF), plutonium science and Advanced Certification. LLNL remained at the forefront of high performance computing software development and hardware acquisition with its significant role in both the CORAL Advanced Technology System (Sierra) acquisition effort and the Exascale Computing Project. LLNL continued to achieve significant efficiencies in NIF and exceeded the stretch goal of 400 shots this year by completing 417 shots. LLNL also fired its seventh high-Z data shot to date, including its first Pu Strength experiment.

Goal 2: Reduce Global Nuclear Security Threats Mission was rated as Excellent as LLNL exceeded nearly all of NNSA's expectations in non-proliferation, emergency management, incident response, forensics, and nuclear counterterrorism. On January 28, 2016, the U.S. DOE and the Kingdom of the Netherlands Ministry of Foreign Affairs hosted Apex Gold, which was the first ever minister-level gathering to identify national and international actions to address a nuclear crisis. The ministers and other senior delegates from 37 nations, along with representatives from the International Atomic Energy Agency (IAEA), the European Union, and the United Nations gathered in Livermore to practice their ability to respond effectively to an emerging nuclear security threat. The participants also toured LLNL to better

understand some of the technical tools available for detecting and analyzing nuclear material and making decisions in the event of a nuclear terrorism crisis. Apex Gold helped to prepare ministers to advise their heads of government during a nuclear security crisis or emergency. The exercise also laid important ground work for the 2016 Nuclear Security Summit, which President Obama hosted on March 30 – April 1, 2016 in Washington, D.C. LLNL played critical technical and logistical roles in the success of Apex Gold. LLNL consistently provided high quality project support on four key Russian nuclear security engagements, projects in Kazakhstan, as well as the International Atomic Energy Agency (IAEA), and subject matter expertise to promote nuclear security cooperation in North Africa, Belarus and Ukraine. LLNL continued to exceed expectations in its support of NNSA's efforts to recover and eliminate radioisotope thermoelectric generators despite our limited ability to work directly with Russia. LLNL continued to provide consistent, skilled support to GMS-NSDD's efforts to further international forensics collaboration. LLNL experts provided key contributions to NNSA's Comprehensive Nuclear-Test-Ban Treaty (CTBT) work in FY 2016.

Goal 3: DOE and Strategic Partnership Project (SPP) Mission Objectives were rated as Excellent as LLNL exceeded nearly all of NNSA's expectations, pursuing and executing high-impact work for DOE and SPP mission objectives. LLNL pursued and successfully executed numerous high impact projects for both the Department and other sponsors that strategically align with NNSA mission objectives. The FY 2016 SPP funding level increased by 15%, or \$40M, over the previous year.

Goal 4: Science, Technology, and Engineering (ST&E) was rated as Excellent as LLNL exceeded nearly all expectations to advance national security missions and advance the frontiers of ST&E in accordance with budget profile, scope, cost, schedule and risk while achieving the expected level of quality, safety and security. LLNL's research consistently remains transformative, innovative, and of high quality as recognized by the ST&E community and validated through various internal and external reviews. LLNL researchers received numerous awards, and their publication rate, patents, and records of inventions continue to climb. LLNL was named to the 2016 Forbes List of America's Best Large Employers, ranking No. 102 out of 500 employers that made the cut. Livermore is the only national laboratory on the list. This ranking places LLNL among the top 10 employers in the San Francisco Bay Area and among the top 12 in government services nationwide.

Goal 5: Operations and Infrastructure was rated as Good. LLNL excelled at maintaining and integrating an enterprise-wide focus and although it exceeded many expectations in effectively and efficiently managing the operations of the Laboratory, it experienced challenges in the area of security incident management. Because of these challenges, LLNL was unable to exceed overall expectations in safeguards and security, which is a critical functional area. LLNL exceeded expectations in the areas of cybersecurity. LLNL achieved an excellent record of safety for the year and exceeded expectations in delivering effective ES&H management, including the areas of worker safety and health, environmental protection, occupational medicine, nuclear operations, radiation protection, and emergency management. LLNL continued to implement long-term work planning and control improvements to ensure safe work execution, but remained challenged by the need for additional resources and funding to achieve successful implementation of the new process. While LLNL provided new strategies and investments to achieve superior facility management results and has become NNSA's "go to" Site for many critical infrastructure initiatives, long-term challenges still remain in deferred maintenance and work order backlogs, especially at Site 300. LLNL continued to deliver efficient and effective business systems,

producing excellent personal property inventory results, leading numerous complex and high dollar value acquisitions on behalf of the enterprise and provided outstanding legal management.

Goal 6: Leadership was rated as Very Good as LLNL exceeded many expectations providing leadership in support of the direction of the DOE/NNSA mission, improving safety culture, the responsiveness of the Laboratory leadership team to issues and opportunities for continuous improvement internally and across the Enterprise, and parent company involvement/commitment to the overall success of the Laboratory and the Enterprise. LLNL demonstrated strategic leadership through its participation and key role in numerous enterprise initiatives, councils, working groups, and collaborations that addressed issues and led to performance improvements. LLNL Director Bill Goldstein served as Chairman of the National Laboratory Directors' Council (NLDC) since December 2015. The NLDC provides a coordinating and integrating function for common issues across all seventeen national laboratories. Changes in key personnel were well coordinated with DOE/NNSA leadership and LLNL provided a high level of transparency, communication, and customer focus, especially with respect to work performed by the NIF organization. Livermore improved the assurance system by better defining risks, establishing joint assessments with LFO to reduce the number of assessments with enhanced focus on potential issues. Of particular significance was the Apex Gold event, which LLNL hosted at the request of the Secretary on January 27 - 28, 2016. LLNL received the DOE Secretary's Honor Awards in recognition of its support during the Iranian negotiations, development of the Energy Quadrennial Technology Review, Laboratory Operations and NNSA infrastructure efforts, and support for addressing the radiological waste release at the Waste Isolation Pilot Plant. However, LLNL management has been slow to acknowledge and take ownership of security performance issues. Additionally, Office of Inspector General (OIG) and LLNL Internal Audit findings on LLNL's Laser Inertial Fusion Energy (LIFE) activities indicate serious management control breakdowns and misalignment of priorities with NNSA.



**Goal 1: Manage the Nuclear Weapons Mission, *Allocated Fee 35%***

Manage the Nuclear Weapons Mission was rated as Excellent as LLNL exceeded nearly all expectations, successfully delivering on our nation's challenging stockpile requirements. LLNL continued to lead the Weapons Laboratories in strengthening the underpinning and future of stockpile stewardship. LLNL performance highlights are set forth below:

- Issued the final Cycle 21 Annual Assessment Reports for the B83, W80, and W87 weapon systems and released the final Laboratory Director letter to NNSA.
- Completed all Independent Nuclear Weapon Assessment Program (INWAP) presentations to the Los Alamos Director for the B61, W76, W78, and W88.
- Successfully completed one Defense Programs (DP) level-1 milestone (1), all DP level-2 milestones (119) on time and within costs, and the Getting-the-Job-Done List (GTJDL) items.
- Fully met commitments for W80-4 Life Extension Program (LEP).
- Met all deliverables and requested actions for weapon surveillance (flight and ground tests) and Limited Life Component Exchange (LLCE) activities.
- Successfully executed shots per the FY16 National Hydrotest Plan.
- Executed Humphrey and Ritter tests as part of the Sierra Nevada subcritical series.
- Made significant progress in the areas of Advanced Manufacturing, Code Development and modeling capabilities, High Energy Density Physics, and the National Ignition Facility (NIF), plutonium science and Advanced Certification (including joint development, with LANL, on a path forward for war-reserve pit production and certification to support stockpile requirements).
- Remained at the forefront of high performance computing software development and hardware acquisition with its significant role in both the CORAL Advanced Technology System (Sierra) acquisition effort and the Exascale Computing Project.
- Continued to achieve significant efficiencies in NIF and exceeded the stretch goal of 400 shots this year by completing 417 shots. LLNL also fired its seventh high-Z data shot to date, including its first Pu Strength experiment.
- Refined additive manufacturing technology, and fabricated and tested additive manufactured development components.
- Completed an extensive set of tests on double pulsing and successfully performed 2D imaging experiments at Contained Firing Facility's FXR.
- Completed first NA-50 "Deep Dive" on 10 years and beyond site requirements.
- Developed a timely and defensible technical basis in support of material equivalency strategy and submittal to enable critical capabilities need to support NNSA stockpile stewardship and LEP requirements.

LLNL met overall cost, schedule, and technical performance in the areas of Nuclear Explosive Safety Studies; Quality Assurance surveys; management of materials & storage programs; implementation of released Nuclear Security Enterprise-wide business requirements, processes, policies; implementation of earned value management, risk management, resource-loaded schedules, program plans, cost controls, configuration management; and successful completion of Office of Secure Transportation task agreements and change control. LLNL continued its exemplary performance in issuing Engineering Authorizations and supporting Product Realization Teams, production and surveillance, and Engineering

Evaluations with other sites. LLNL successfully imported six Weapon Response Code (WRC) data into CASTLE for the LLNL weapon systems. LLNL deployed a new enhanced Engineering Authorization (EA) tool for PRIDE to provide a consistent tool that all NSE sites can use and that is more sustainable going forward. LLNL reconfigured PDMLink data in preparation for data migration for the Windchill Redeployment Project.

LLNL developed an Implementation Plan to execute DOE/NNSA Agency Nuclear Enterprise Assurance related program activities in accordance with NAP-24A Attachment 4, DOE O 452.1E and DOE O 452.4C. In Pu Sustainment, LLNL completed the seismic anchoring of the first set of Recovery Line gloveboxes with factory acceptance tests and initial installation of the second set, and supported W87 pit design, development, and certification by obtaining approval in March for shipping Engineering Development Unit (EDU) and development (DEV) pits. LLNL also developed – with LANL – a path forward for war-reserve pit production and certification to support stockpile requirements. This plan is currently being implemented to achieve WR production of the next newly-manufactured pit type. LLNL delivered input to the DPP-3 PRT. LLNL led the DPP-1 PRT, completed the Conceptual Design Review, and submitted the Model FL Safety Analysis Report for Packaging (SARP) to the NNSA Office of Packaging and Transportation (OPT). LLNL was on schedule for submitting a disposition plan for the UC-609 containers as requested. LLNL did not meet some requirements, specifically having an NNSA-approved Quality Assurance Plan (QAP) for the DPP-1 design. Not having an approved QAP will delay effort of the DPP-1 in FY 2017.

LLNL successfully staffed surveillance activities across the four LLNL systems (W80, B83, W84, and W87) in accordance with directive documents and within budget. LLNL supported the W78 GT217 flight test down range at Kwajalein on February 21, supported POM and JTA meetings, and began mission planning for GT221 with the DoD. In support of Cycle 21 Annual Assessment, LLNL developed and issued the final Cycle 21 Annual Assessment Reports for the B83, W80, and W87 weapon systems and released the final Laboratory Director letter to NNSA. LLNL also completed all Independent Nuclear Weapon Assessment Program (INWAP) presentations to the Los Alamos Director for the B61, W76, W78, and W88. LLNL completed the W87 detonator and JTA assemblies, and provided onsite support at Pantex for critical flight-test component and test unit assembly operations. LLNL also refined the assessment of performance under stockpile-to-target sequence (STS) conditions for the W87 using ASC engineering code model updates to demonstrate significant improvement in the quality of primary inputs to secondary models; engineering analysis made significant progress in understanding response to specific in-flight environments. The LLNL Pit Surveillance Program completed four pit High-Resolution Computed Tomography (HRCT) analysis reports. LLNL completed 3-D simulations to address an issue particular to the W80 design, completed LLNL Design Agency (DA) Trending Report for W80 Detonator Cable Assemblies (DCAs). LLNL quickly responded to Significant Finding Investigation (SFI) notifications, and there are no current High Priority SFIs remaining. LLNL also successfully executed a hydrotest at the Contained Firing Facility (CFF) as part of the process for technology maturation and verification and validation in support of future stockpile options and assessments. LLNL completed the B83 Primary and Secondary nuclear design reviews in support of the Annual Assessment Review; thermo-mechanical testing of a mock primary subassembly; reassessment of nuclear performance impact supporting an SFI; and two potential significant findings were investigated and closed with no impacts. LLNL completed subject matter expert (SME), Engineering and Physics reviews of stockpile systems in support of the Director's Annual Assessment. LLNL completed peer reviews of the B61-12 LEP and W88 Alt 370. LLNL



assisted with the Inter-laboratory reviews presented to NA/HQ on March 28, 2016 for the B61-12 LEP and on April 4-7, 2016 for the W88 ALT 370. LLNL provided the required inputs for the November 2015 and May 2016 Weapon Reliability Reports (WRR).

LLNL performed W80, B83, W84, and W87 maintenance and LLCE activities as planned and within budget. LLNL completed the B83 Product Realization Team (PRT) activities for the B83 Electronic Neutron Generator on time and within budget. LLNL delivered their Weapons Dismantlement and Disposition Plan on time. LLNL completed FY16 weapon component disposition activities in accordance with their disposition plan. LLNL completed the W87 Nuclear Explosives Safety Study (NESS) in March 2016 without findings resulting in reauthorization of the weapon system. LLNL completed the W84 NESS resulting in authorization in September 2016. LLNL completed the W80 ALT 369 requalification activities on time. LLNL provided weapon response support to meet evolving requirements and resolve issues with limited weapon response resources. Other W80 ATL 369 authorization included SS-21 rule mapping and Hazardous Analysis Task Team (HATT) walk down, weapon response related testing, drafting the W80 Technical Basis Document, and supporting the ALT 369 Gate E Review. LLNL exceeded its FY16 goal to characterize 350 weapons parts and dispose/consolidate 150 weapons parts; specifically, LLNL characterized 624 parts and identified 341 of these for disposal at the Nevada Nuclear Security Site (NNSS). While LLNL provided weapon response support to meeting evolving requirements and resolve issues, LLNL weapon response peer review activities resulted in an emerging issue that will drive process and tooling changes at PX. NNSA is negotiating actions required to resolve this issue in order to minimize impact to operations and scheduled activities. Upon review of the sequence of events, it appears there are opportunities to improve the internal WR peer review process to better support meeting project deliverables. Earlier collaborative effort and identification of additional resources are mitigation options available to enable more effective support of the project deliverables. Finally, constrained weapon response resources contributed to the overall delay in meeting the baseline ALT 369 project FPU.

LLNL demonstrated the application of new strategies, technologies, and scientific understanding to support stewardship of the existing stockpile and future stockpile needs, performing all work as planned, within budget profile, scope, cost, and schedule. All of the thirty-six Level-2 milestones under this Objective were completed ("Blue") by the end of the year. The planning phase deliverables for the Joint Technology Demonstrator (JTD), which supports a JTJDL item, were completed in January, and the multi-agency JTD team had initiated authorization by April.

Additive Manufacturing - LLNL leadership in Additive Manufacturing (AM) continued to drive the pace of the programs at the Labs, and hosted the 2<sup>nd</sup> AM Cross-JOWOG meeting in February. LLNL chose AM pads as the default option for a specific application, fielded AM cushions in a successful test, printed 10 WR parts and 20 cushions for future tests, and continued progress in AM-produced metals. In addition, LLNL drafted a report on cushion technologies for the JASON.

Primary Assessments - The boost 10-year strategy has been coordinated and a plan was completed. The plan focuses on physics hypotheses to resolve certain physics questions, as well as proposed experimental validation data needs. In support of the Certification Readiness Exercise, data from a December LLNL hydroshot at CFF has been shared with LANL, and LLNL executed a second related hydrotest at the Dual-Axis Radiographic Hydrodynamics Test (DARHT) in September. LLNL has developed new analysis tools to identify possible sources of code errors in the extensive quantity of lines

within its performance codes. The Primary Metrics Project (PMP) now contains 231 events, and a new template for mesh generation allows easier 2-D to 3-D conversions, resulting in a substantial increase in performance calculations and demonstrating progress toward 3-D PMP work in the out years. Insensitive High Explosives Component Qualification is making good progress as 1) LLNL is preparing to use Photonic Doppler Velocimetry (PDV) diagnostics on the side and back of the initiation train to increase data collection in area of interest for corner turning of Insensitive High Explosives (IHEs), and 2) High Explosives (HE) components are in the queue to be machined at S-300. LLNL performed IHE Component Qualification and Characterization for reactive flow models in Support of Science and the Stockpile. LLNL also completed the Time Projection Chamber (TPC) FY16 data collection at Los Alamos Neutron Science Center (LANSCE) with 55 Terabytes of data relevant to neutron cross sections.

Secondary Assessments - For high fidelity Equation of State (EOS) measurements of a particular material, the first campaign shots were performed on December 16 at Omega, and the preliminary assessment is that the shots produced good data. These experiments tested the convergent geometry EOS platform and assessed the Uncertainty of Secondary Performance Using a Proposed Modern Methodology for Uncertainty Quantification method.

Subcritical Experiments - LLNL completed a Sierra Nevada Project Execution Plan which details milestones and schedule with collaborating partners (LLNL, LANL, and NSTec). LLNL also completed a baseline resource schedule (plan) created using the Primavera tool. LLNL named a Point-of-Contact (POC) for Red Sage Diagnostics. The POC will be responsible for the technical and operational coordination between the LANL Red Sage experimental team and the LLNL diagnostic experimental team. A second technical lead has been named for the development of the Multi-Wavelength Extinction (MWE) diagnostic. LLNL actively worked with LANL and NSTec within the U1a Complex user model to field the Subcritical Experiment (SCE) program. LLNL worked to ensure key fielding work scope was funded after the loss of Lab Logistics funding. LLNL personnel learned that LANL personnel needed a new qualified vendor for the Toxic Industrial Material (TIM) filters used in the SCE vessel venting system. LLNL personnel had just solved a similar problem with TIM filters used at the Joint Actinide Shock Physics Experimental Research (JASPER) facility, and offered its vendor information to LANL. By teaming with LANL, LLNL personnel allowed LANL to avoid a significant cost on the upcoming LANL Eurydice surrogate SCE. LLNL supported the design and fabrication of the "Humphreys" over-pressure qualification test conducted at LANL in August and the "Ritter" test conducted at the Atomic Weapons Establishment (AWE) in September in support of Sierra Nevada.

Dynamic Material Properties - LLNL developed prototype microwave interferometry diagnostic for use in Sierra Nevada and future subcritical experiments. LLNL completed the JASPER infrastructure and diagnostics. LLNL successfully met at least 8 JASPER shots per the joint LLNL/NSTec program plan of which at least 3 are performed on actinide targets, including experiments using the Graded Density Impactor technology. LLNL developed and evaluated New Explosive Molecules for the Stockpile. New high explosive molecular crystals will be synthesized, scaled up, and evaluated for performance. The most promising explosive molecules for future stockpile applications will be identified. Past results on new high explosive molecular crystals will be summarized and analyzed. LLNL developed a plan for Pu Aging R&D. The plan includes a summary of recent work for annual assessment reviews and pit reuse options and will layout a set of investigations of Pu aging for principal stockpile alloys relevant to future pit reuse and stockpile assessments.

Pu Aging Studies - LLNL performed Transmission Electron Microscopy (TEM) measurements to characterize helium (He) bubbles in an approximately 50 year-old, naturally aged Pu alloy sample, with results demonstrating that He bubbles have not grown in diameter compared with measurements made on this material at the 42- and 46-year-old marks. LLNL determined that void swelling has not appeared, and is not occurring in these materials. LLNL also developed a kinetics model code capability and free energy models, with input from its Pu EOS team, and performed atomistic simulations to parameterize certain aspects of the kinetics model.

Advanced Certification - LLNL successfully conducted Certification Readiness Exercises to explore and develop new technologies for potential application to the stockpile and to identify and mitigate certification issues. Additive Manufacturing (AM) of a subcomponent in support of design options for an upcoming LEP will be developed and executed. Subcomponent will be characterized against preliminary subcomponent requirements. LLNL successfully developed, and demonstrated the feasibility of fabricating a polymeric material via AM technology for potential use in future LEPs. Hydrotests were successfully conducted demonstrating the feasibility of this technology, in time to support NA-10's down select decision coming up in FY17. In support of this Certification Readiness Exercise, data from a December LLNL hydroshot at CFF has been shared with LANL, and LLNL has delivered the hardware related hydrotest at DARHT. The shot was successfully executed. LLNL continued to leverage and develop approaches to improve utilization of aboveground experimental (AGEX) data and capabilities to enhance confidence of future stockpile assessments and certification.

Advanced Radiography - LLNL supported the Conceptual Design of U1a Complex Enhancements Project (UCEP) for ECSE. LLNL reconfigured pulsed power to admit interleaved operation of injector and J-block of the FXR accelerator to produce double electron pulsing at 10 MeV endpoint energy.

Enhanced Surety - LLNL completed FY16 full-system compatibility test, development of surety sub-system option, and Multi-Point Safety (MPS) activities on time and within budget. LLNL completed a pump down and backfill system design and assembly. LLNL established upgraded X-ray Photoelectron Spectroscopy (XPS) capability in Superblock (B332) and successfully explored equipment capability for high vacuum, temperature, and pressures for Multi-Point Safety (MPS) testing. LLNL fabricated hardware and leak check certified; completed Authorization Safety Basis Evaluation.

Research and Development (R&D): LLNL completed FY16 nuclear safety R&D development and nuclear explosive package (NEP) development activities on time and within budget. LLNL demonstrated progress in technology maturation for NEP technologies and effectively collaborated with the United Kingdom,

Joint Integrated Lifecycle Surety (JILS) - LLNL completed JILS FY16 activities on time and within budget. LLNL developed better ways to present cost benefit results (Titled - Cost Aided Risk of LEP Surety (CAROLS)), which supports current and future LEPs.

Engineering - In support of the Engineering Program, LLNL completed all Level 2 milestones on time and within scope. LLNL performed a sensitivity study on PBX 9502 material (formulated with new TATB) and conducted relaxation tests and axial torsion tests on legacy cushion materials at low temperature.

LLNL continued to provide input into a draft National Survivability strategy and anticipates producing a final report during the first quarter of FY17. LLNL completed NNSA's FY16 GTJDL item regarding modeling of weapon flight dynamics and continues developing the Warhead Hostile Environment Survivability Plan (WHESP). LLNL completed, tested, and mounted a 12"x12" monolithic GLO scintillator and is awaiting Pantex evaluation.

LLNL sustained unique science and engineering capabilities, facilities and essential skills to ensure current and future Nuclear Weapons mission requirements are met, performing all work within budget profile, scope, cost, and schedule. Of the twenty-nine Level-2 milestones, all are completed "Blue". The Contained Firing Facility's FXR completed an extensive set of tests on double pulsing and successfully performed 2D imaging experiments. The double-pulse capabilities are planned for use in an FY17 experiment in support of the Sierra Nevada series. LLNL, SNL, LANL, and NSTec have developed a joint proposed statement of work focused on risk reduction activities for ECSE technology (ECSE and NDSE). LLNL developed and began testing of a Transportable Hydrotest Experiment (THE) system, a portable LLNL firing/diagnostics capability incorporating traditional S300 firing facility capabilities and systems developed for the Phoenix program into portable blast-resistant containers located near the experiment location. The system will be controlled via remote-control trailer. The system capabilities include timing, digitizers, firing system, portable x-ray, PDV, fiber Bragg system, video surveillance, and control/safety. LLNL significantly improved its computational capabilities with the successful construction of B-654, which was completed ahead of schedule and under budget. B-654 is the program's new data center and will house two new high-performance computing systems (started delivery this year). One will be used for classified computing and the other will be used for institutional computing and to support the Predictive Science Academic Alliance Program (PSAAP) II. Consistent with the acquisition schedule, LLNL has deployed a single scalable unit of the Commodity Technology System-1 (CTS-1) procurement, which will support the objective of debugging TOSS 3.0 on these CTS machines. LLNL has done an extraordinary job leading the continuing Tri-Lab procurement of these next generation CTS machines. In a similar leadership vein, LLNL has also played a proactive role in leading the Tri-Lab effort to ensure that HQ personnel have a robust knowledge of current developments in high performance computing as well as an in-depth understanding of the history of the effort. With respect to Advanced Technology Systems, LLNL continues to exceed expectations with regard to the management of the Sierra acquisition. LLNL succeeded in ensuring the non-recurring engineering (NRE) and build contracts were approved for the ASC Sierra system, in addition to the collaboration of Oak Ridge, Argonne and Livermore (CORAL) contract negotiations. LLNL continues to meet schedule milestones on the Sierra contract activities. LLNL is also on track to port and verify existing ASC codes onto FY16 deployed systems and is also diligently working to develop codes that will more effectively utilize advanced computing architectures, like Sierra. Work has thus begun to integrate improvements into application codes. In addition, LLNL is working to ensure the desired performance portability will be achieved on these future platforms by developing a new generation of codes specifically adapted to evolving HPC architectures. LLNL is also investigating Neuromorphic computing, including the procurement of testbeds, consistent with the requirement to support advanced, next-generation computing technologies as mandated in the 2015 National Strategic Computing Initiative. LLNL is in the process of developing a Tri-Lab usage model for the system and is in the process of training individuals on using the machine. Infrastructure and Operations (I/O) facilities were operational 95% of scheduled days (in comparison to the target of 85%), noting the very fast recovery time to storm-related closures at S-300. The B334 E-Beam Welder was commissioned and is being used to fabricate test articles for programmatic work.

LLNL executed product realization processes and activities in support of nuclear weapon life extension programs, modification and alterations in accordance with NNSA requirements and Nuclear Weapons Council guidance, performing all work within budget profile, scope, cost, and schedule. LLNL supported the B61-12 System Development Engineering by delivering the Inter-Laboratory Peer Review report on March 28, 2016. LLNL hosted the W88 ALT 370 Refresh Peer Review Deep Dive in April 2016 that included more than a dozen LANL participants providing in depth information for review by LLNL SMEs including Design Physics, Engineering, and Materials Science SMEs, and covering component changes, qualification plans, and surveillance plans. LLNL hosted the Enhanced Collaboration EC12 planning meetings for Phase 3 in February for safety/surety technology approaches of interest, with LLNL, LANL, SNL, and AWE participation. Inter-lab EC12 discussions including aspects relating to JTD were held in May to discuss LLNL MPS work to date and how EC12 will interface with and support related JTD efforts.

LLNL executed shots on NIF in support of the Stockpile Stewardship Program in accordance with the NIF Governance Plan, while continuing to improve the efficiency of NIF operations with a constrained operating budget, performing all work on target as planned, within budget profile, scope, cost, and schedule. LLNL successfully executed 417 shots at NIF, which exceeded the goal of 400 shots in FY16. The Laboratory conducted the first programmatic shots using the Advanced Radiographic Capability (ARC) on NIF, and completed the first successful demonstration of the convergent EOS platform at Omega to validate and improve the platform for NIF shots later in the year. NIF HED experiments included a series of experiments with different pulse shapes and cone fractions that enabled them to map out the strategy toward a symmetric implosion configuration at low gas fill for future 2-shock experiments, including layered DT 2-shock experiments. The Laboratory commenced simulations using the Arbitrary Lagrange Eulerian (ALE) code called ARES, an ARES simulation of a subset of high-foot DT implosions. NIF executed the 7th High-Z diffraction data shot to date, acquiring scientifically significant data at the highest pressure to date. NIF also continued the development of the diffraction platform, including 2 X-Ray Source (2XRS) shots on March 15. LLNL executed the first high-Z strength experiment on NIF in May. NIF also conducted four integrated Ta RT Strength Experiments and obtained high quality face-on radiography data and also conducted experiments to develop higher-pressure drive on NIF. LLNL hosted the "High-foot" workshop in March to review the implosion campaign, and a review report was issued in May (milestone 5454) and worked with NNSA to complete the document, "2016 Inertial Confinement Fusion Program Framework" to determine the efficacy of reaching ignition. LLNL hosted the HED Council meeting in March that recommended a prioritized set of Q1-Q2 FY17 experiments on NIF. For the SSP-ICF program, LLNL executed an OMEGA Foam Bubbles campaign shot day in March with several different nickel (Ni) foam densities, measuring the shock location over a range of times for both directly- and indirectly-driven targets. The goal is to develop a pairing of materials that retain similar hydrodynamic behavior. This new technique is essential for measuring the full mix width in NIF experiments, where instabilities can be driven for several e-folding into the nonlinear regime. LLNL executed four strength Rayleigh-Taylor (RT) experiments on NIF in late March, acquiring significant data on all diagnostics. These experiments included measurements tantalum (Ta) growth at 3.5 and 5 Mbar at different times. Also, LLNL conducted the first 2-Shock experiment designed to measure mix from a deliberately asymmetric implosion. Imaging indicates the capsule hydrodynamics was as expected with the symmetry phase reversal observed during stagnation; neutron signals (mix data) are being analyzed. LLNL executed three radiation transport experiments with the objective being to measure the radiation propagation in a complex configuration. The predicted feature of interest was not observed, and LLNL is

assessing possible issues. The Laboratory executed a 5-shot material phase campaign in late May, including the first successful liquid diffraction measurement at NIF where lead was shocked to 0.8 Mbar, melted, and x-ray diffraction was used to observe the diffuse line profile, a signature of the lead (Pb) liquid state. LLNL conducted a ramp compressed platinum EOS experiment on NIF in late April, measuring stress density response at high pressure and high strain rate and demonstrating maturation of the ramp compression platform on NIF. The initial data analysis showed very good agreement on results obtained on both NIF and Z for platinum in similar regimes. Furthermore, LLNL conducted a 5 Mbar Equation of State NIF experiment in aluminum to examine proposed phase transitions. All 12 milestones were successfully completed ("Blue").

LLNL executed stockpile-relevant special nuclear material experiments and integrated experiments and strengthened the technical foundation for LEP options with a focus on the W80-4, performing all work as planned, within budget profile, scope, cost, and schedule. All six L2 milestones are "Blue". Two shots for technology maturation in support of future LEPs were successfully executed: a "pin" shot at CFF in December and a complementary shot at DARHT in September. The shot at CFF demonstrated two "firsts," the first all-optical pin hydro and the first shot to use a specific part made through an additive manufacturing process. For the first time, the LLNL Diamond Anvil Cell (DAC) team has imaged the pressure-induced solidification/melt of crystal in a metal (Ga). Four hydrodynamic experiments are currently under development for the W80-4 primary design certification, investigating various refresh options that require minimal changes and that are exploring various replacement materials as well. In order to address the throughput issues for the parts associated with the above W80-4 hydrotests as well as tests for other programs, LLNL has started "pre-building" more components for hydrotest and subcritical experiments through 2030. As part of its recapitalization plan, LLNL is continuing the design of 128 channels of MPDV for CFF to support upcoming test needs, and the vault at B801 is being upgraded to support these. A "hot soak" hydrodynamic test for an LLNL system was successfully conducted at CFF in April. LLNL successfully conducted a Phoenix Full-Function Test FFT-6 in April at LANL. As part of the Sierra Nevada program, LLNL successfully fired the "Ritter" experiment at AWE in August with 100% data capture and achieved of the experimental goals. LLNL also executed the successful confinement vessel overpressure test "Humphreys" at LANL. In the area of Pu aging, LLNL completed cold testing of Nano Dilatometer instrumentation to measure swelling in aged material, demonstrating detection limits of 2 nanometers, which will enable detecting PuGa alloy swelling from aging in approximately two weeks. LLNL is the only lab studying this area. Also in support of Pu aging, LLNL initiated "hot" operations for the newly commissioned Scanning Auger Nano probe to characterize aged surfaces in a stockpile alloy, completed TEM analysis of a 50 year old stockpile alloy, showing data consistent with normal aging in these alloys without any evidence of void swelling, and submitted Pu aging contributions to the L1 Reuse Milestone report. The first Addendum to the FY 2016 National Hydrodynamic Test Plan submitted in late FY 2015 was submitted to NNSA on schedule in October 2015 (milestone 5427), the second and third addenda were submitted on schedule in P2. LLNL completed JASPER milestone of 11 shots, 5 of which were actinides. A campaign with graded density impactors on two surrogate and three alpha Pu samples was completed. The shots returned exceptional data in a pressure and temperature regime with little previous experimental data and provide new insights into the dynamic behavior of Pu. JASPER shots also included shot a surrogate shot to confirm the deployment of a new pyrometry diagnostic system, and a shot to test the radiometry and new Optical Beam Break (OBB) systems. LLNL was also instrumental in addressing the JASPER target shipping issue, and the issue is now resolved to allow resumption of target shipments to the Nevada Nuclear Security Site (NNSS).



LLNL investigated the implementation of multiple diverse hydrodynamic schemes within the context of a single full system code, defined and pursued a viable computer science framework as the foundation of a next generation integrated design code, and managed the Sierra contracts effectively, executing the acquisition strategy and meeting all schedule milestones under program control while coordinating closely and regularly with Argonne National Laboratory and Oak Ridge National Laboratory. LLNL performed all work as planned, within budget profile, scope, cost, and schedule. The three L2 milestones were all "Blue" at year-end. CORAL efforts are on-schedule, and the Non-Recurring Engineering work is on track to complete in 2Q 2017 as planned. LLNL has made good progress on the node and system roadmap and engage in exceptional collaborations with ORNL and Argonne on CORAL activities. Sandia and LANL are included in meetings and all working groups. LLNL is participating in the management of the Exascale Computing Project (ECP) jointly managed by DOE NNSA and DOE Science. The team is preparing for a Design Review of the project after successfully completing in January an Independent Cost Review of ECP's 10-year budget. The ECP team also successfully completed a key milestone in April, approval of the Critical Design 0 (Mission Need). LLNL demonstrated integration of 11 times speedup performance into ASC codes, through the integration of RAJA. This is being implemented across three production ASC applications using lessons learned from the 2015 L2 milestone, focusing on the ALE-3D project. LLNL released RAJA as part of the CS toolkit capabilities for modular hydrodynamic options (milestone 5587), and is working closely with the Sierra and Trinity COE vendors to ensure RAJA can provide the desired performance portability. For Advanced Architectures and Portability Specialists (AAPS) milestone 5588, LLNL shared the AAPS strategy document with the Advanced Technology Development and Mitigation (ATDM) lead and other program managers. The AAPS team has added more skilled computational scientists in multiple code teams, performing a variety of tasks and building and expanding the LLNL knowledge of the codes. Basic functionality of the Data Store, a key component of the computer science framework, has been completed and has been implemented in a limited extent into one of LLNL's current ASC production codes for testing and robustness. A prototype of one component of the Computational Science (CS) Toolkit, an inline visualization tool called Strawman, was distributed to AWE for testing. LLNL developed an initial version of a main driver code and created abstract "simulation" class interface for driving either ALE or Eulerian hydro libraries. LLNL created an initial unified build and test system and completed initial *Application Programming Interface* (API) and implementation of SiDRe (in-memory datastore). This includes support for sharing data across codes written in different programming languages. LLNL also helped review the draft Request for Proposal for the 2020 ASC system acquisition expected to be sited at LANL (Crossroads).

LLNL effectively executed W80-4 LEP Phase 6.X programs in accordance with program-specific and NNSA Project Controls System directives, including Earned Value Management System development, in order to (1) meet schedule, (2) comply with Phase 6.x Process and Product Realization Processes, (3) lower risks, (4) control change, and (5) control costs. LLNL successfully ramped up the W80-4 project team, and established a Project Controls System for Earned Value Management System (EVMS) Requirements. LLNL developed a detailed matrix showing how LLNL's work is addressing schedule, Phase 6.x processes, lowered risks, change control, and cost control. LLNL developed a High Level Earned Value Management (EVM) implementation plan and developed a detailed plan on integration testing for EVM tools. LLNL has commenced numerous infrastructure activities including heat-treat recapitalization, facility prep planning for a horizontal saw, and Digitizer procurements. LLNL installed and configured Active Risk Manager (ARM) software on the iSRD network ahead of schedule per requirements of the W80-4 LEP Risk Management Plan. LLNL is the lead site for Risk Management and is currently working on classified

cross-site deployment to all NSE sites. LLNL implemented “DOORS” (Dynamic Object-Oriented Relational System, a requirements management software tool) for the W80-4 LEP program. LLNL drafted Derived system requirements based on Military Characteristics (MC) focusing on robust requirements management and traceability processes. LLNL participated in the Warhead Option Working Group (WOWG) to define Phase 6.2A design options and gained Nuclear Weapons Council Standing and Safety Committee (NWCSSC) concurrence, documenting scope associated with design choices, analyzing requirements, and generating preliminary risk statements to support future risk scoring activities. LLNL also hosted the W80-4 LEP Integrated Project Team (IPT) to discuss program planning and activity status with representatives from NNSA HQ (NA-14, NA-18, NA-19), the labs, and plants. LLNL finalized the PRT structure, completed the initial round of PRT discussions with program management at Y-12, PX, LANL, and NSC, and a number of LLNL-led PRTs started before the end of FY16.

**Goal 2: Reduce Global Nuclear Security Threats, Allocated Fee 15%**

Reduce Global Nuclear Security Threats Mission was rated as Excellent as LLNL exceeded nearly all of NNSA's expectations in non-proliferation, emergency management, incident response, forensics, and nuclear counterterrorism. On January 28, 2016, the U.S. DOE and the Kingdom of the Netherlands Ministry of Foreign Affairs hosted Apex Gold, which was the first ever minister-level gathering to identify national and international actions to address a nuclear crisis. The ministers and other senior delegates from 37 nations, along with representatives from the International Atomic Energy Agency (IAEA), the European Union, and the United Nations gathered in Livermore to practice their ability to respond effectively to an emerging nuclear security threat. The participants also toured LLNL to better understand some of the technical tools available for detecting and analyzing nuclear material and making decisions in the event of a nuclear terrorism crisis. Apex Gold helped to prepare ministers to advise their heads of government during a nuclear security crisis or emergency. The exercise also laid important ground work for the 2016 Nuclear Security Summit, which President Obama hosted on March 30 – April 1, 2016 in Washington, D.C. LLNL played critical technical and logistical roles in the success of Apex Gold.

LLNL consistently provided high quality project support on four key Russian nuclear security engagements, projects in Kazakhstan, as well as the International Atomic Energy Agency (IAEA), and subject matter expertise to promote nuclear security cooperation in North Africa, Belarus and Ukraine. LLNL continued to exceed expectations in its support of NNSA's efforts to recover and eliminate radioisotope thermoelectric generators despite our limited ability to work directly with Russia. LLNL continued to provide consistent, skilled support to GMS-NSDD's efforts to further international forensics collaboration. LLNL experts provided key contributions to NNSA's Comprehensive Nuclear-Test-Ban Treaty (CTBT) work in FY16. Examples include the May 2016 Nevada Familiarization Activity, the first time CTBT on-site inspection (OSI) experts visited the former U.S. nuclear explosive test site, and strong contributions to developing OSI training efforts. LLNL also hosted the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO) Preparatory Commission Executive Secretary for a visit in November 2015. LLNL continued to offer strong technical support to the office's international export control outreach program having provided a subject matter expert (SME) for five international workshops. LLNL also provided outstanding technical support in developing a key piece of the Information Technology infrastructure for the Office's licensing work and performed outstanding technical end user analyses. However, there is room for improvement in the timeliness of these end user reviews, which can be resolved by LLNL bringing on more staff to support this function. LLNL SME provided exceptional support for the safeguards engagement in North Africa, South America, and Southeast Asia. LLNL provided outstanding support for multiple safeguards policy and human capital development projects, including support for U.S. policy initiatives designed to ensure International Atomic Energy Agency (IAEA) safeguards implementation is effective, technically credible and non-discriminatory under the State-level concept. LLNL played a critical leadership role in the low-yield nuclear explosion monitoring (LYNM) campaign, and has exceeded all expectations for effectiveness. LLNL discovered an ancient tectonic plate using their geophysical three-dimensional tomographic model of the Earth, which was developed to improve seismic monitoring. This fundamental geoscience discovery was featured as an editor's choice in Science Magazine. LLNL led high explosives (HE) operations during the successful planning and execution of the Source Physics Experiment (SPE)-5, leading field test preparations for HE operations, timing and firing for the SPE-6 shot. LLNL successfully developed prototype time series

processing algorithms designed for “Big Data” applications, as research outcomes that another government agency incorporated in their analyses of seismic events. A LLNL researcher gave an invited lecture on global seismic tomography in Munich, of a scientific discovery that was enabled by the high fidelity and discriminating power of their three-dimensional tomographic imaging methods of the earth’s interior. LLNL conducted quality nuclear forensics research that was presented at the April 2016 Defense Nuclear Nonproliferation (DNN) R&D nuclear forensics program review. LLNL successfully developed and demonstrated prototypical software for optimal deployment of radiation detection resources to support planned search and clear missions such as the State of the Union, Super Bowl, etc. LLNL expanded the understanding of soot formation and speciation by conducting a series of realistic experiments that replicated overdriven HE conditions. LLNL led Nuclear Counterterrorism coordination efforts in direct support of updating the DOE Design Basis Threat Policy, a key nuclear security endeavor. In addition, LLNL provided excellent support to vital international meetings; continued advancing global counterterrorism efforts, and provided excellent execution of targeted IND characterization efforts in support of NCT efforts to evaluate IND modeling sensitivities. LLNL also developed specialized technical products to support a high profile international summit. NARAC supported both Apex Gold and the President's Scenario-Based Policy Discussion at the 2016 Nuclear Security Summits. These were extraordinary and highly/globally visibly efforts. The Radiological Assistance Program (RAP) continued to exceed expectations in outreach and engagement with federal and regional partners. LLNL supported the Render Safe and Lincoln Blue programs. LLNL supported Stabilization training and Home Team support. LLNL completed all of its RAP deliverables, but not all of them on time. More specifically, LLNL provided RAP training with the San Francisco FBI FO in support of TRNSO TTP’s. LLNL supported the Nuclear Forensics Post-Detonation, Pre-Detonation, and Materials Analysis Programs. LLNL performed tasks in accordance with written guidance and maintained operational readiness for DFO and DFEAT. LLNL produced monthly reports on nuclear smuggling and maintaining the International Exchange Program to provide plume modeling capabilities to international partners. Finally, LLNL continued excellent execution of standoff disablement activities, including timely delivery of critical assessments requested by DoD.

LLNL supported efforts to secure, account for, and interdict the illicit movement of nuclear weapons, weapons-useable nuclear materials and radiological materials. LLNL provided exceptional project support to the Offices of Global Material Security (GMS) and Radiological Security (RS). Its responses to tasks, budget reporting, travel and project logistics, and contracts management have been timely and of high quality. LLNL managed to make significant progress in its assigned areas despite the challenges of traveling to Russia, Congo, and Namibia, which have unstable regional governments or limitations imposed for political reasons. LLNL provided valuable support to Radiological Security in the areas of threat evaluation, prioritization methodology and cyber protection needs. Additionally, LLNL supported and had a nominee for the IAEAs Integrated Nuclear Security Support Plan (INSSP) expert Mission to Congo. LLNL provided consistently high quality project support on four key Russian nuclear security engagements, to the Kazakhstan Nuclear Security Training Center, as well as nuclear security best practices engagement with China, and the International Atomic Energy Agency (IAEA). An LLNL subject matter expert promoted nuclear security cooperation with North African countries and was able to schedule an event with a country of interest. The LLNL subject matter experts (SMEs) assigned to these projects, the LLNL management, and the LLNL support personnel have consistently provided a high level of support. All existing Russian nuclear security work has been authorized under the FY15 National Defense Authorization Act. (NA-22) LLNL supported NSDD’s international nuclear forensics work and is

currently leading eleven bilateral engagements in eleven countries, as well as engagements with the IAEA in support of the development of guidance documents. LLNL conducted quality nuclear forensics research that was presented at the April 2016 DNN R&D nuclear forensics program review. LLNL provided good support to the US Department of Energy at the Commissariat à l'Energie Atomique (COMENA) joint Technical Security Working Group meeting in Algeria. LLNL expertise was valuable to the joint delegation to assist in implementing security requirements of nuclear/radiological materials, sites, and transportation.

LLNL effectively supported U.S. national and nuclear security objectives in reducing global nuclear security threats through the innovation of unilateral and multi-lateral technical capabilities to detect, identify, and characterize: 1) foreign nuclear weapons programs, 2) illicit diversion of special nuclear materials, and 3) global nuclear detonations. (NA-22) LLNL exceeded expectations in advancing signal processing techniques that have the potential to significantly improve the volume and speed at which seismic data can be processed. LLNL developed and improved innovative processing algorithms, and successfully developed prototype time series processing algorithms designed for "Big Data" applications. LLNL delivered an integrated architecture for coupling advanced strategic codes with algorithms capable of predicting physical mechanisms leading to signal of interest generation in expanded time and space scales. An LLNL researcher gave an invited lecture on global seismic tomography in Munich. In addition, LLNL exceeded expectations in demonstrating advanced techniques to discover an ancient tectonic plate using its geophysical three-dimensional tomographic model of the Earth, which was developed to improve seismic monitoring and was featured in a national science publication. LLNL also provided outstanding leadership in developing a program around challenges of low-yield nuclear evasive monitoring. LLNL exceeded expectations in its support of the Source Physics Experiment (SPE) 5. The experiment resulted in exceptional data return and improves the United States Government's (USG) capability to detect and characterize underground nuclear explosions. LLNL had a leading role in this fifth experiment of the series, and an LLNL staff member served as the Chief Scientist. Because of the success of the experiments, five LLNL staff members were awarded Certificates of Merit by NNSA Office of Nonproliferation Research and Development. LLNL exceeded expectations in its support of the NA-22 efforts in a cooperative research agreement with the UK. The LLNL team was involved in the planning, flight and ground measurements, and ground truth information collection. The data which was collected was of higher quality than expected by the team. Collaboration between governments can be a challenge in of itself, without considering technical challenges that can arise in this type of research. The success of this effort can only help ensure the possibility of future collaborations between the NNSA and the UK, strengthening ties between the two countries and strengthening security globally. LLNL provided exceptional support to the Underground Nuclear Explosion Signature Experiments (UNESE) as evidenced by an LLNL staff member being chosen as the Chief Scientist. As part of its support, LLNL had an article published in the journal *Nature*. The editor of *Nature* has reported that this article is in the top 5% of articles reviewed from the journal this year.

LLNL effectively supported efforts to achieve permanent threat reduction by managing and minimizing excess weapons-useable nuclear materials and providing nuclear materials for peaceful uses. LLNL continued its support of the NNSA Office of Global Threat Reduction (NA-21) and engagement in Russian nuclear sites project closeouts. LLNL provided a high level of support to the IAEA through workshops, meetings, and providing instructors for valuable courses. LLNL provides a valuable service to the United States Government (USG) by educating IAEA member states in nuclear security matters. This service

ensures that IAEA is current on new methods, systems, system performance, improving standards, and promoting continuous improvement. LLNL provided excellent support to the Office of Defense Nuclear Nonproliferation (DNN) in the area of cyber security at nuclear and radiological facilities. An LLNL staff member was appointed the training lead for the DNN Cyber Support Team, and LLNL developed a one-week course on how to develop a cyber security program, which is intended for an international audience. Improving cyber security at nuclear facilities domestically and internationally is imperative, and LLNL provides valuable service to the USG and international nuclear security customers. LLNL in conjunction with Idaho National Laboratory taught the first class to twenty members of the Kazakhstan Government and other nuclear industry personnel in Almaty, Kazakhstan.

LLNL effectively support efforts to prevent proliferation, ensure peaceful nuclear uses, and enable verifiable nuclear reductions in order to strengthen the nonproliferation and arms control regimes, executing programs in DNN's Office of Nonproliferation and Arms Control (NA-24). This office has three major areas, International Nuclear Safeguards (NA-241), Nuclear Export controls (NA-242), and Nuclear Verification (NA-243). LLNL exceeded expectations in all of these areas by providing intellectual leadership and world-class technical support during FY16. (NA-24) LLNL completed many key activities in an exceptional manner. These key activities included hosting the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) Executive Secretary in November 2015 to demonstrate NNSA's commitment to the CTBTO. LLNL performed in a manner that exceeded expectations on two panels at the CTBTO Symposium (Science & Diplomacy for Peace & Security) in January 2016 in Vienna, Austria. LLNL experts were key members of the U.S. delegation at CTBT Working Group B (WGB-46) in Vienna, Austria, in February-March 2016. An LLNL expert also attended and contributed to the discussion at the CTBT P5 experts meeting on the margins of WGB-46. LLNL was recognized by the NNSA Deputy Administrator for Defense Nuclear Nonproliferation for its continued exceptional intelligence support on countries of concern, playing a key role in developing the technical program for the May 2016 CTBTO On-Site Inspection (OSI) Familiarization Activity at the Nevada Nuclear Security Site (NNSS).

LLNL is the lead laboratory for the NA-243 Seismic Cooperation Program. This program has focused on developing seismic expertise in countries in the Middle East and Central Asia. In May, LLNL subject matter experts visited Dushanbe, Tajikistan to conduct a seismological analysis and seismic hazard workshop. Also, LLNL conducted a regional workshop in Kazbegi, Georgia using data from regional networks of Armenia, Azerbaijan, Georgia and Turkey and LLNL completed training for Iraqi seismologists through our university collaboration in Arkansas. Located near the New Madrid fault zone, site of the most powerful earthquake ever to hit the continental US, the Arkansas Earthquake Center has been a well-known and respected leader in earthquake research and education since its founding in 1991. A LLNL employee was selected as a surrogate inspector trainee in the 3<sup>rd</sup> round of training with the Comprehensive Test Ban Treaty Organization. An expert in the application of radiation detection equipment and nuclear emergency response field operations, the employee will begin training to become an inspector beginning in October 2016 and will bring his broad skills to the regime. The US only put 5 people forward for this 3<sup>rd</sup> training cycle across all DOE labs. LLNL continued to provide high quality support to the Graphite Isotope Ratio Method (GIRM) project, conducting Secondary Ion Mass Spectrometry measurements of qualification samples in a timely manner. In addition LLNL continued to provide high quality support to the Uranium Sourcing Database project, running samples, maintaining the database, and coordinating project activities involving two other laboratories. LLNL ably supported the transition to the single US Government (USG) licensing Information Technology (IT) system (USXPORTS) by developing a new IT system for end user reviews (SNAApp) and helping integrate the new



SNApp into USXPORTS as well as other key pieces of the IT architecture at Oak Ridge National Laboratory (ORNL) and Los Alamos National Laboratory (LANL). LLNL provided exceptional support through the conduct of export control technical reviews, thousands of end-user reviews for U.S. Department of Commerce (DOC) export license applications, and DOE Part 810 cases and nuclear software code requests. While the technical quality of the reviews continued to be outstanding, the reviews often left insufficient time for DOE HQ adjudication within the mandated 30 day response deadline. Although LLNL has been provided with sufficient funding, it needs additional technical staff to address the backlog and delays on required export control reviews. LLNL provided technical expertise on emerging technologies to help inform policy decisions on classification and export control. LLNL continued to competently support Commerce's Information Triage Unit (ITU) by sharing its reviews. LLNL provided superior technical support for an International Nonproliferation Export Control Program (INECP) Technical Introduction to Licensing workshop in Rabat, Morocco. Also, as technical co-event lead with the SRNL, LLNL provided support for a Balkans Regional End-Use/End-User Workshop, which was held in Montenegro. LLNL participated in 38<sup>th</sup> proficiency test Organization for the Prohibition of Chemical Weapons (OPCW) and received an "A" grade. This demonstration of proficiency allows LLNL to be an accredited OPCW laboratory which is a necessary requirement for NA-24's support to this international agreement. LLNL provided exceptional analysis in support of Weapons of Mass Destruction (WMD) interdiction activities; provided exceptional support in for safeguards engagement in North Africa, South America, and Southeast Asia, including a first-ever Additional Protocol implementation workshop in Laos; met its milestones to fabricate Pu-244 certified reference materials from ultra-high purity Pu-244 samples that were retrieved from Russia; and provided exceptional support for multiple safeguards policy and human capital development projects, ranging from support to the U.S. Interagency Safeguards Review to preparation of a safeguards course for the intelligence community. LLNL has performed superbly in instituting the tiered model to one country and intends to include another country relevant to subject matter discussed within the interdiction efforts. LLNL actively participated in Plutonium Verification Team training at a research reactor and hot cell facility in the Republic of Georgia. LLNL also actively participated in Uranium Verification Team training held at the Oak Ridge National Laboratory. LLNL is helping to train the next generation of safeguards experts through the NA-241 Human Capital Development Program. In May of 2016, LLNL held an "Understanding the IAEA: A Nuclear Nonproliferation Seminar" for U.S. Government analysts at the DCI National Counterterrorism Center; nine LLNL analysts and consultants participated in the instruction of the course. The course was exceptionally well-received, and NA-241 was asked to have LLNL organize another iteration of the course at a later date. Also LLNL held an "Environmental Sampling at the IAEA" workshop, immediately following the "Understanding the IAEA" seminar. LLNL was a critical participant in the Uranium Hexafluoride (UF<sub>6</sub>) Age Dating project. LLNL provided headspace gas sampling, UF<sub>6</sub> sample analysis, and radiometric clock evaluation expertise. LLNL continued to provide noteworthy support to the Uranium Sourcing Database project, running samples, maintaining the database, and coordinating project activities involving two other laboratories. An LLNL subject matter expert actively participated in the Plutonium Verification Team (PVT) training at Savannah River National Laboratory, working very well with the other members of the PVT, eagerly building knowledge, experience, and team cohesion through lectures, tours and exercises. A LLNL subject matter expert did an exceptional job working closely with the co-lead of the Uranium Verification Team (UVT) to develop a training program for the UVT to be held later this year at Oak Ridge National Laboratory (ORNL) and Y-12. LLNL has been selected to stand up an IT system to support the DOE contributions to the Joint Comprehensive Plan of Action (JCPOA) and has supported the JCPOA technical expert meeting by providing the DOE senior technical expert to the U.S.

delegation.

LLNL continued its exceptional support of the International Nuclear Safeguards and Engagement Program (INSEP) as the lead lab for the North Africa region, completing technical engagements in Algeria and Tunisia. LLNL continued to provide leadership for the Design Review team under the U.S.-UK Portal Monitor for Authentication and Certification (PMAC) project. LLNL has performed an exceptional job monitoring different requests for design and other material review, working with other members of the team and UK counterparts to coordinate input, and providing sound technical feedback as the project progresses.

LLNL sustained and improved nuclear counterterrorism and counterproliferation science, technology, and expertise; executed unique emergency response missions, implemented policy in support of incident response and nuclear forensics missions, and assisted international partners/organizations. (NA-80) LLNL performed NA-83 Materials Analysis, pre-detonation, and post-detonation tasks in accordance with written guidance and maintained operational readiness in support of the Disposition and Forensic Evidence Analysis Team (DFEAT) and the DOE Forensics Operations team (DFO). Schedule and budget for all tasks are on track. LLNL completed 12 out of 15 Technology Integration Program (TI) deliverables. While LLNL completed all of its Radiological Assistance Program (RAP) deliverables, timeliness of deliverables needs to be improved. LLNL provided support to Stabilization Program training as well as assisting in the transfer of material from Pantex to the Device Assembly Facility (DAF). LLNL sustained strong participation in NCT inter-laboratory technical meetings to evaluate Improvised Nuclear Device (IND) modeling sensitivities and in the Joint Disablement Campaign (JDC), an interagency working group in support of render safe activities. In support of the JDC, LLNL continued to perform excellent preliminary development efforts for a tool to assist in predictive disablement modeling. LLNL provided strong support addressing outcomes from international meetings with the U.K. and France enhancing bi-lateral and tri-lateral Nuclear Threat Reduction exchanges, including excellent execution of open source initiatives. LLNL continued to improve and operate the world class National Atmospheric Release and Advisory Center (NARAC), which provides the U.S., State, and local government decision makers with chemical, biological, and radiological dispersion simulations. NARAC provided simulations to the Nuclear Security Summit 2016 and was recognized as a valuable and necessary tool by the White House. LLNL also provided exceptional support to a one week national post detonation nuclear forensics exercise and an LLNL staff member received the Discreet Oculus Top Contributor of the Quarter award for the second quarter FY16.

LLNL excelled at serving as a lead site and providing key support on high-profile Department non-proliferation initiatives with international partners, including Ministerial Exercises and hosting foreign dignitaries and VIPs in support of the Nuclear Security Summit. On Jan. 27-28, the Department of Energy and the Kingdom of the Netherlands Ministry of Foreign Affairs hosted Apex Gold at Lawrence Livermore National Laboratory. Ministers and other senior delegates from 37 nations, and representatives from the International Atomic Energy Agency, the European Union and the United Nations participated in an emerging nuclear security threat exercise. LLNL played a critical role in the very successful Apex Gold exercise.

LLNL executed nuclear threat device "task list" and materials work and standoff disablement experimental and modeling efforts, supported other new technologies and capabilities, and provided

leadership in the assessment of open source information. (NA-80) LLNL performed well in targeted IND characterization efforts in support of meetings to evaluate modeling sensitivities. LLNL sustained exceptional execution of and engagement in all standoff disablement activities, including completion of an interagency Standoff Disablement Roadmap and timely delivery of critical assessments requested by DoD, and produced two quality reports collecting and assessing open source reporting on nuclear smuggling for specific audiences. LLNL completed predictions of two underground nuclear tests and analyzed data from a series of FY 2015 standoff disablement experiments. The experimental results provided more valuable data than expected. LLNL was able to quantify some existing uncertainties in design codes by benchmarking against criticality safety knowledge. LLNL provided exceptional support to the National Mission Force by modeling disablement methods and quantifying uncertainties of the modeling efforts through experimentation. LLNL provided consequence analyses of potential INDs by utilizing a large database of INDs that were initially developed for post detonation nuclear forensics work. This effort could provide invaluable information to those who would respond to a potential nuclear device. An LLNL staff member received a Letter of Appreciation from the Director NA80 to recognize exceptional efforts in the area of Nuclear Counterterrorism.

LLNL effectively managed and maintained readiness for deployable response and home teams, trained and developed new and existing staff to become qualified responders, supported operations, exercises, and drills, and maintained measurement capabilities. (NA-80) LLNL ensured continued enhancements to NNSA emergency response capabilities. LLNL maintained its emergency response equipment and personnel training qualifications. LLNL maintained and managed the IXP system, providing a key international capability under the Response and Assistance Network. In addition, LLNL provided reliable and expert support for exercises, training and outreach. LLNL also contributed specialized technical products to two high profile international meetings, exceeding expectations. LLNL provided exceptional support and responded to 580 drills, 748 communication tests, 78 Event Adjudication Level (EAL) 1s (including responses in support of San Francisco Fleet Week, Albuquerque Balloon Fiesta, Rose Bowl, Super Bowl preparations, and NHL playoffs) and 25 actual events (medical patients, medical waste at a landfill, Barnwell, Nevada fire, WIPP, cargo shipments, Aerial Measuring System (AMS) flights, home storage of materials). LLNL also participated in the national-level emergency drill where LLNL deployed two trainees and supported the event with 6 home team members. In addition, LLNL participated in two other drills, a Department of Justice drill in Alaska, and a Phase 1 bilateral drill in Phoenix. LLNL also received national program approval for two LLNL employees as qualified Joint Technical Operations Team (JTOT) responders. LLNL participated in the IAEA International Conference on Global Emergency Preparedness and Response on October 19-23 in Vienna. LLNL continued its exceptional Radiological Assistance Program (RAP) outreach to FBI, local police departments, fire departments, and other organizations as requested. For example, RAP team members provided training at the request of Sacramento FBI Weapons of Mass Destruction Coordinator with over 40 participants from the FBI, regional bomb squads, fire departments, police departments, and hazmat units. Technical training was also provided to the DOD Civil Support Team (CST), Coast Guard, and Guam first responders on short notice to backfill for the RAP region 8. RAP has added additional team members (six) to ensure that the program is well staffed to meet NNSA mission needs.

### Goal 3: DOE and Strategic Partnership Project Mission Objective, Allocated Fee 5%

DOE and Strategic Partnership Project Mission Objectives were rated as Excellent as LLNL exceeded nearly all of NNSA's expectations, pursuing and executing high-impact work for DOE and Strategic Partnership Project (SPP) mission objectives. LLNL pursued and successfully executed numerous high impact projects for both the Department and other sponsors that strategically align with NNSA mission objectives. The FY16 SPP fund level increased over 15%, or over \$40M, as compared to FY15. SPP highlights include:

- **LLNL Supports NYC Subway Biodefense Test:** Lawrence Livermore researchers took to the New York City subway system to help study how a biological agent, such as anthrax, might disperse throughout the nation's largest rapid transit system as a result of a terrorist attack or an accidental release. The LLNL-developed technology DNATrax was a key component of the bio aerosol agent dispersion test. The study is part of a five year Department of Homeland Security (DHS) project called Underground Transport Restoration (UTR) and was conducted in accordance with the National Environmental Policy Act.
- **Global Security Hosts a Nonproliferation Workshop:** The Center for Global Security Research and Global Security Directorate hosted a two-day workshop on the future of nonproliferation. The workshop brought together researchers from the Lab as well as representatives from the state and federal levels to identify future research opportunities for the technical communities. The group engaged in discussions on five main areas: arms control, threat reduction, nonproliferation, counter proliferation, and counter nuclear terrorism. LLNL's Pat Falcone and Brad Roberts, along with former Livermore Director Michael May participated in the discussion.
- **Lab Physicist Receives DoD Award:** Lab employee Craig Wuest was awarded the Office of the Secretary of Defense Medal for Exceptional Public Service in recognition of his work to strengthen DoD's nuclear survivability posture and his role as executive secretary for the Defense Science Board Task Force on Deterring, Preventing and Responding to the Threat or Use of Weapons of Mass Destruction.

LLNL published numerous articles and received numerous awards based on their high-impact work.

- *Philosophical Transactions of the Royal Society A* published a LLNL cover article on catalyst development to explore an integrated design process for catalysts. This process uses nanoporous gold to define reactivity and then predict new reactive pathways rather than traditional trial and error experimentation.
- In December 4, 2015, *Science* published an article on LLNL's research work, which described a new table top ultraviolet laser for generating soft x-rays to provide a powerful new tool for basic research and technological applications.
- In October 28, 2015, *Physical Review Letters* published an LLNL article which described the first improvements in 50 years in measuring particle interactions involving neutrinos emitted in radioactive decays. LLNL results confirmed the current theory and demonstrated an alternate approach to testing the Standard Model that rival direct searches at high energy colliders.
- LLNL research demonstrated carbon nanotubes could transport protons ten times faster than water and faster than state of the art fuel cell membranes. The article appeared in *Nature Nanotechnology*.

- To help support grid resilience with renewables an innovative storage system to provide backup to intermittent generation was proposed. A multi-institutional team led by LLNL describes a subsurface energy system. Behaving like a massive underground battery, the system could store renewable energy and dispatch electricity to the grid throughout the year. An article was published in the December 2015 issue of *Mechanical Engineering* magazine.
- Computer biochemical simulations enable development of safer neuroactive drugs through model studies of molecular dynamic simulations of nervous system neurons published in April 2016. A LLNL and IBM neural network system conducts complex cognitive tasks far more efficiently than conventional chips is used to explore new computing capabilities.
- *Applied Physics Review* published a paper in January 2016 by LLNL on physics models for powder bed fusion advance manufacturing. Selective laser melting (SLM) process was modeled from powder to finished part manufacturing to improve scientific understanding of the advanced manufacturing process.
- April 2016 reports demonstrated a new class of foam applications from 3D printing with higher durability and long term mechanical performance that impact automotive, aerospace, electronics, defense and medical applications. A cover article in *Advanced Materials* March issue demonstrate 3D material dynamic behavior improvements over conventional explosive material manufacturing techniques.
- A *Scientific Reports* article describes an innovative strategy for combining 3D printing and subsequent folding with conductive materials to build complex structures. This new process creates a unique material with potential wide spread applications in manufacturing, medicine and material science.
- LLNL earned an R&D 100 award for development of a process called projection microstereolithography. This process enabled production of large components with extremely small features in a single manufacturing stage.
- New LLNL computations developments were awarded the *Gordon Bell Prize* in 2015 for Sequoia supercomputer mantle convection simulations using the full capabilities of the supercomputer.
- CORAL is a first-of-its-kind DOE collaboration between the NNSA's ASC Program and the Office of Science's Advanced Scientific Computing Research program (ASCR) that will culminate in three ultra-high performance supercomputers at Lawrence Livermore, Oak Ridge, and Argonne national laboratories. *HPCWire* recognized the team with an *Editor's Choice Award* for Best HPC Collaboration for the work to bring the Sierra supercomputer to LLNL in late 2017.

LLNL successfully pursued and performed high-impact work for DOE that strategically integrates with the DOE/NNSA mission. This work had large impacts in basic sciences and applied technologies.

- *Philosophical Transactions of the Royal Society A* published an LLNL cover article on catalyst development to explore an integrated design process for catalysts. This process uses nanoporous gold to define reactivity and then predict new reactive pathways rather than traditional trial and error experimentation.
- LLNL's Large Underground Xenon (LUX) dark matter experiment followed years of work to improve sensitivity to enable evaluation of previous potential detections. This paper was submitted to the *Physical Review Letters*.
- In December 4, 2015, *Science* published an article on LLNL's research work, which described a new table top ultraviolet laser for generating soft x-rays to provide a powerful new tool for basic research and technological applications.

- In October 28, 2015, *Physical Review Letters* published an LLNL article which described the first improvements in 50 years in measuring particle interactions involving neutrinos emitted in radioactive decays. LLNL results confirmed the current theory and demonstrated an alternate approach to testing the Standard Model that rival direct searches at high energy colliders.
- LLNL new starts included (a) a five-year program in switchgrass cultivation for carbon sequestration, soil fertility and biodiversity; and (b) Trilab consortium to design solid state materials to store hydrogen gas for Fuel Cell Technologies over three years.
- New research modeled projected impacts of carbon emissions over long time frames, cloud effects of brightness on temperatures, C sequestration in brine subsurface formations and cosmic ray formation of C14 at high altitudes. All these recent high-impact papers continue to support LLNL as a world class climate science center in DOE.
- LLNL physics programs developed an antineutrino detector to conclusively address an unresolved central question of neutrino physics. Another effort was development efforts on beyond the standard model searching for understanding of hints of new particles from results at Large Hadron Collider (LHC) in Europe.
- New materials innovations included hexagonal diamond by shock compressions similar to meteorite impacts traces. A cover article published in Royal Society journal described new catalysis materials from nano-porous gold funded by DOE Office of Basic Energy Sciences.
- LLNL research demonstrated carbon nanotubes could transport protons ten times faster than water and faster than state of the art fuel cell membranes. The article appeared in *Nature Nanotechnology* and on the DOE Office of Basic Energy Sciences website. The work has important implications for more efficient fuel cells to power cars and other electrical equipment.
- *Applied Physics Review* published a paper in January 2016 by LLNL on physics models for powder bed fusion advance manufacturing. Selective laser melting (SLM) process was modeled from powder to finished part manufacturing to improve scientific understanding of the advanced manufacturing process.

LLNL excelled in pursuing and performing high-impact Strategic Partnership Projects that strategically integrates with the DOE/NNSA mission. The FY16 funding level increased by 15% or \$40M over FY15. Below are examples of Strategic Partnership Projects (SPP) that strategically integrated with the DOE/NNSA mission.

- DARPA-sponsored project for \$4.6 million over 36 months. In collaboration with the University of Pennsylvania and Medtronic, Inc., LLNL is developing a neural electrode array to record and stimulate from the central nervous system in order to understand and possibly treat memory disorders. The electrode array will interface with neurons in the brain and connect externally to a neuromodulation system developed by Medtronic.
- DTPA-sponsored project for \$2.4 million over 60 months. The effort included determining and documenting nuclear weapon outputs (e.g. neutrons, gamma radiation, X-rays and debris) that could be expected from historical U.S. nuclear weapon and test device detonations, and then to use the data to facilitate understanding of weapon outputs to support the effects work of DoD agencies, the military services, and operational commands.
- DHS-sponsored project for \$2.5 million over 36 months. In collaboration with Carnegie Mellon University, LLNL developed and implemented an Enhanced Radiological Nuclear Inspection and Evaluation (ERNIE) system designed to help classify and analyze radiation alarms.



- DoD Missile Defense Agency (MDA)-sponsored project for \$23.2 million over 12 months. LLNL's work included continuing to improve the system and component performance of the hydrocarbon-free diode pumped alkali laser (DPAL) scheme to the level required for demonstrating a subscale system. This work firmly established the LLNL approach as suitable for compact, light-weight, electrically-driven, high efficiency, excellent beam quality, power-scaled laser systems of interest to the MDA. Specifically for FY16, the primary program focus was the demonstration of a key DPAL point design, through design, fabrication, integration, and test of a laboratory-based laser (Alpha), at a level that establishes traceability to MDA mission requirements. The secondary FY16 focus was the conceptual design of a DPAL system for flight-traceable performance demonstrations at progressively increasing power levels.
- Northrop-Grumman Corp.-sponsored a continuing project for \$2.573 million over the next 24 months. LLNL's Phase 2 effort in the area of micro-materials and devices included work in three areas, namely, power generation, micro-structured surfaces for adhesion, and *Microelectromechanical Systems* (MEMS) devices for attachment.
- DTRA-sponsored project for \$2.0 million over 20 months. The continued effort included researching the development of a tool to align electro-optical and infrared images of multi-view imagery using 2D image registration techniques on parallax disparity maps derived from these two modalities. LLNL evaluated the feasibility of using these techniques on satellite-based low-earth orbit, other imagery, and other national technical means. LLNL also co-registered two 3D models created from calibrated multi-view stereo with other 3D models using LiDAR, or any additional third modality of multi-view imagery.
- DARPA-sponsored project for \$6.96 million over 43 months. LLNL, in collaboration with the University of California Los Angeles, Gen8 and Boston Scientific, developed a neural electrode array to record and stimulate from the central nervous system in order to understand and possibly treat memory disorders.
- DHS-sponsored project for \$3.9 million over 36 months. LLNL continued to the Consensus Threat Space, and provided support for System Threat Reviews and other technical support. The purpose of this work was to better understand the radiological/nuclear threat facing our nation.
- Army-sponsored project for \$925 thousand over 24 months. Army Research Laboratory (ARL) and LLNL scientists collaborated to advance the state-of-art capabilities in collecting computed tomography data on platforms that use flash (~100 nanosecond duration) x-ray sources. This work included optimizing hardware and geometry of the source/detector pairs, and integrating software to reconstruct images with the least amount of noise.
- Department of Defense (DoD)-Air Force: \$2.69 million over 18 months. In collaboration with University of California, Los Angeles and the Charles Stark Draper Laboratory, LLNL developed the Light-field Directing Array (LDA) cell system. Specifically, the project developed essential closed loop control capabilities, fabrication and assembly of the high performance elements into working mirror cells in an array, and a systems engineering analysis to generate a roadmap for integration into desired applications of a future, matured technology.
- Department of the Treasury: \$15 million over 60 Months. LLNL addressed the needs for the United States Currency Program (USCP) to discover and evaluate technologies that may be suitable for incorporation into U.S. currency as a security feature. The scope of the work was a market survey and assessment of security features and technologies. This market survey and evaluation included procurement and/or laboratory analysis of materials, prototypes, and technologies. The USCP's primary focus and the scope of LLNL's study were on public features, however, technologies that are

appropriate for all end users are of interest. LLNL identified opportunities for innovative technology development.

- Army Corps of Engineers: \$3.43 million over 36 months. LLNL demonstrated software and technology developed within DOE for both static and dynamic analysis of software (firmware). LLNL also demonstrated a process for applying this technology to mitigate cyber risk within the context of facility maintenance and protection within the DOD base electrical substations and building automation systems.
- DoD-Air Force: \$4.5 million over 24 months. LLNL developed a photonic RF-to-digital receiver, which will convert analog signals into a high resolution digital output. This digital output may be tailored to meet the requirements of various military applications for covert communications, advanced RADAR, remote sensing, high capacity airborne/satellite data links, etc.

LLNL fully leveraged its capabilities and demonstrated effective execution of energy, climate, high performance computing, and basic science research work in support of DOE cross-cutting initiatives. Below are activities in each area, from energy to computing research.

### **Grid Modernization**

- To help support grid resilience with renewables, LLNL proposed an innovative storage system to provide backup to intermittent generation. LLNL led a multi-institutional team which described a subsurface energy system. Behaving like a massive underground battery, the system could store renewable energy and dispatch electricity to the grid throughout the year. An article was published in the December 2015 issue of *Mechanical Engineering* magazine.
- LLNL worked on 14 new grid research projects as part of the Grid Modernization Initiative. This Initiative represents a comprehensive DOE effort to help shape the future of the nation's grid and solve the challenges of integrating conventional and renewable sources with energy storage and smart buildings, while ensuring that the grid is resilient and secure to withstand growing cybersecurity and climate challenges.
- New solar array to generate power was commissioned at LLNL for the first in the western regions and the largest on DOE sites.
- LLNL released open source power system simulator titled GridDyn for use of the California Energy System 21<sup>st</sup> Century project and Pacific Gas and Electric utility.
- LLNL's efforts in power systems engineering included an integrated grid management framework software development for end-to-end power delivery system.
- LLNL submitted a report to the Office of Electricity, which showed that active scanning can be successfully employed in energy delivery system environments to improve resilience to utility cyber-attacks.

### **Climate Investigations**

- *Nature Climate Change* article developed model results of ocean warming and evaluated the estimates of ocean warming over a range of depths and times.
- LLNL led the earth system grid federation conference in December 2015 to coordinate the consortium of agencies and institutions in extreme scale scientific data with respect to climate measurements worldwide.

- LLNL's *Nature* article in December 2016 compared climate model precipitation estimates to observational results to support improvements in worldwide model development.
- LLNL climate scientist was elected a fellow of the American Meteorological Society (0.02% annually) based on the results of his leadership in LLNL climate program and the DOE Accelerated Climate Modeling for Energy (ACME) program.
- New LLNL research modeled projected impacts of carbon emissions over long time frames, cloud effects of brightness on temperatures, carbon sequestration in brine subsurface formations, and cosmic ray formation of Carbon-14 at high altitudes. All these recent high impact papers continue to support LLNL as a world class climate science center in DOE.

### **Advanced Manufacturing**

- *Applied Physics Review* published a paper in January 2016 by LLNL on physics models for powder bed fusion advance manufacturing. Selective laser melting (SLM) process was modeled from powder to finished part manufacturing to improve scientific understanding of the advanced manufacturing process.
- LLNL gained advanced understanding of reactive (explosives, etc.) 3D printing of complex shapes, which improved the control of products based on the architecture of the reactive materials.
- LLNL earned an R&D 100 award for development of a process called projection microstereolithography. This process enabled production of large components with extremely small features in a single manufacturing stage.
- California Network for Manufacturing Innovations (CNMI) met at LLNL to discuss emerging advance manufacturing processes. This meeting hosted at LLNL demonstrated the lead of the national lab in advanced manufacturing processes.
- April 2016 reports demonstrated a new class of foam applications from 3D printing with higher durability and long term mechanical performance that impact automotive, aerospace, electronics, defense and medical applications. A cover article in *Advanced Materials* March issue demonstrate 3D material dynamic behavior improvements over conventional explosive material manufacturing techniques.
- A *Scientific Reports* article describes an innovative strategy for combining 3D printing and subsequent folding with conductive materials to build complex structures. This new process creates a unique material with potential wide spread applications in manufacturing, medicine and material science.

### **Advanced Scientific Computing Research (ASCR)**

- New LLNL computations developments were awarded the *Gordon Bell Prize* in 2015 for Sequoia supercomputer mantle convection simulations using the full capabilities of the supercomputer.
- CORAL is a first-of-its-kind DOE collaboration between the NNSA's ASC Program and the Office of Science's Advanced Scientific Computing Research program (ASCR) that will culminate in three ultra-high performance supercomputers at Lawrence Livermore, Oak Ridge, and Argonne national laboratories. *HPCWire* recognized the team with an *Editor's Choice Award* for Best HPC Collaboration for the work to bring the Sierra supercomputer to LLNL in late 2017.
- Computer biochemical simulations enable development of safer neuroactive drugs through model studies of molecular dynamic simulations of nervous system neurons published in April 2016. A LLNL and IBM neural network system conducts complex cognitive tasks far more efficiently than conventional chips is used to explore new computing capabilities.

- LLNL and IBM researchers won a Best Paper award from the Institute of Electrical and Electronics Engineers (IEEE) for a paper demonstrating highly scalable implementation of first principles electron dynamics coupled with molecular dynamics with the award to be presented later this year.

**Goal 4: Science, Technology, and Engineering (ST&E), Allocated Fee 10%**

Science, Technology, and Engineering (ST&E) was rated as Excellent as LLNL exceeded nearly all expectations to advance national security missions and advance the frontiers of ST&E in accordance with budget profile, scope, cost, schedule and risk while achieving the expected level of quality, safety and security. LLNL research consistently remains transformative, innovative, and of high quality as recognized by the ST&E community and validated through various internal and external reviews. LLNL researchers received numerous awards, and their publication rate, patents, and records of inventions continue to climb. A climate researcher received the DOE Secretarial Honor Award for his leadership of the Accelerated Climate Modeling for Energy project. The DOE Secretarial Honor Award was also presented to an LLNL team for participation in an Office of Intelligence and Counterintelligence Analytic Team significantly contributing to understanding of a growing foreign nuclear threat. Another researcher received an early career award from the Office of Science to join 12 previous award-winners. A LLNL scientist/engineer was awarded the 2015 Surety Transformation Initiative (STI) Award from NNSA's Enhanced Surety Program. NNSA Administrator presented awards to six LLNL scientists/engineers for support to the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) on site field exercises. LLNL continues to win Research and Development (R&D) 100 awards. LLNL was awarded 3 R&D 100 awards, which now brings LLNL's total to 155 R&D 100 awards since 1978. LLNL also has implemented a Partnering and Educational Outreach program, received many awards, and had notable speakers talk at LLNL, which all help to maintain a healthy and vibrant research environment.

LLNL was named to the 2016 Forbes List of America's Best Large Employers, ranking No. 102 out of 500 employers that made the cut. LLNL is the only national laboratory on the list. This ranking places LLNL among the top 10 employers in the San Francisco Bay Area and among the top 12 in government services nationwide.

LLNL made steady progress in the areas of technology transfer/partnerships and implementation of DOE's public access plan. A number of initiatives are being deployed, such as, the National Laboratory Entrepreneur Academy and LabCorps to assist scientists in moving LLNL ideas, such as, promising clean energy into industry applications. The new CalCharge consortium is bringing together industry, academic, and DOE national laboratory representatives at LLNL to work on energy storage collaborations, while the new DOE High Performance Computing for Manufacturing program has funded \$5 million for work in the manufacturing technologies for clean energy. A key partnership agreement project, the High-Repetition-Rate Advanced Petawatt Laser System (HAPLS) hit an important milestone, achieving a target average energy level for the pump laser. Technology transfer success was recognized by awards from NASA Ames and from the Federal Laboratory Consortium Far West Region.

LLNL continues on track for research that is transformative, innovative, leading edge, high quality and advances the frontiers of science and engineering. New publications in high impact journals, (such as *Science* and *Nature*), and covers of those journals, demonstrate the world-class caliber of the work that push the frontiers of science in addition to the recognition that LLNL scientists and engineers are receiving in a broad array of technical fields. LLNL scientists and collaborators discovered elements 115, 117, and 118. That raises LLNL's total discoveries to six new element, including 113, 114, and 116. Each heavy element was detected in a short half-life with sophisticated separation and analytical techniques.

As part of the international research team, LLNL scientists discovered five new atomic nuclei. The isotopes of uranium, neptunium, two of americium, and berkelium were detected using a new, fast and highly sensitive separation and detection system. These discoveries and technical innovations place LLNL in the top worldwide rank of heavy element research. In December 2015, *Science* published an LLNL article which described a newly discovered more efficient regime for generating soft x-rays with a table top ultraviolet laser. In December 2015, climate science at LLNL continued with recent groundbreaking publications in *Nature* with an analysis of model global precipitation estimates versus observations. A *Nature Climate Change* article in January 2016 addressed global ocean heat uptake in recent decades, and impacts in models and observations to improve understanding of the global distribution of energy fluxes.

LLNL executed a research strategy that is clear and aligns discretionary investments (e.g., LDRD) with Laboratory strategy. The FY16 LDRD program/projects support current and future mission investments in five LLNL Strategic Focus and seven Core Competencies areas. The 5 Strategic Focus areas are 1) Chemical and Biological Security; 2) Cyber Security, Space, and Intelligence; 3) Energy and Climate Security; 4) Inertial Fusion Science & Technology; and 5) Stockpile Stewardship Science. The 7 Core Competencies areas are 1) Advanced Materials and Manufacturing; 2) Bioscience and Bioengineering; 3) Earth and Atmospheric Science; 4) High-Energy-Density Science; 5) High-Performance Computing, Simulation, and Data Science; 6) Lasers and Optical Science and Technology; and 7) Nuclear, Chemical, and Isotopic Science and Technology. LLNL's rigorous processes, including call for proposals, concept paper development, assessment of strategic alignment, and scientific peer review, ensured that the portfolio is of the highest quality and was highly aligned with the DOE, NNSA, and LLNL national security missions. LLNL's LDRD program has funded 172 projects that support current and future mission investments in the five Strategic Focus (SF) and seven Core Competencies (CC) areas. Below are a few high-impact, innovative R&D results and capabilities that are well aligned with LLNL missions:

- LLNL LDRD research appears on the inside cover of a March edition of the *Journal of Materials Chemistry A*. The article discusses how their research found that certain metal oxides composites increase the capacity and improve the cycling performance of lithium-ion batteries, basically higher capacity, longer lasting lithium-ion batteries. These composites are of great interest for their potential in energy storage and conversion, catalysis, and sensors.
- LLNL LDRD researcher was selected as one of two recipients of a Young Researcher Award by the Nanodiamond Symposium organizers at the 2016 Spring Materials Research Society meeting in Phoenix, Arizona. The award recognizes outstanding early career researchers working with nanodiamond particles that presented their results at the symposium in Phoenix. The award was for his work on "Measurements of Nanodiamond Formation During Detonation Using Time-Resolved Small-Angle X-Ray Scattering" which was an outgrowth of an LDRD project.
- Two LLNL researchers have been selected by the DOE Office of Biological and Environmental Research and the Office of Fusion Energy Research, respectively, as recipients of DOE Office of Science Early Career Research Program awards. The awards provide \$500,000 per year for five years for development of individual research programs of outstanding scientists early in their careers, and stimulate research careers in disciplines supported by the DOE Office of Science. This year, 49 awardees were selected from a pool of about 720 applicants. Both of the LLNL awardees received initial support from LLNL's LDRD Program.
- A team of researchers from LLNL and the University of California at Santa Cruz has doubled the



performance of three-dimensional-printed graphene-based super-capacitors. They have developed a method for enhancing the capacitance of graphene-based electrodes without sacrificing their conductivity or structural integrity. This method involves two ion-intercalation steps, or insertion of ions between material layers. The team's work, supported by LDRD project 14-SI-004, "Deterministic Multifunctional Materials and Manufacturing Initiative" led by Christopher Spadaccini, is described in a paper in the June, 2016 online edition of ChemNanoMat, and will be highlighted on the back cover of an upcoming print edition of the journal.

- LLNL LDRD research appears on the June 2016 online edition of Nature Communications. A team of Lawrence Livermore and Northwestern University researchers have combined bio-inspired technology with three-dimensional printing to create the first reactor that can continuously produce methanol from methane at room temperature and pressure. This research could lead to more efficient conversion of methane to energy production.
- A team of LLNL LDRD researchers has demonstrated that three-dimensional printing of shape-shifting structures that can fold or unfold to reshape themselves when exposed to heat or electricity. This team is the first to combine the process of direct-write three-dimensional printing and subsequent folding with smart materials to build complex structures. The micro-architected structures were fabricated from conductive, environmentally responsive polymer ink developed at LLNL. In a paper published in 2016 edition of *Scientific Reports*, the team reported on their strategy for creating boxes, spirals, and spheres from shape-memory polymers, which are bio-inspired "smart" materials that change shape when heated. To create these materials, special resins are printed into complex forms and then, when only partially cured, are folded into a desired primary shape in the same manner as paper is folded to create origami figures. Once the parts are fully cured and cooled, they can then be reheated and formed into new, secondary shapes. Once cooled, the parts will remain in the secondary shapes as long as they are not heated. However, if they are reheated, either through application of direct heat or electricity, they will return to their original primary folded shape. Biologically based shape-memory polymers are attractive because of their potential biodegradability and biocompatibility, while being derived from inexpensive and abundant renewable resources. The ability of polymers to recover their original shapes will be advantageous for a broad range of applications including aerospace and as flexible circuits in robotic devices.

LLNL finalized the FY2017 LDRD program plan (PP). The LDRD PP which consisted of 182 projects, two-thirds of these projects were continuing projects, and the balance were new projects. As with the previous portfolios, individual projects/proposals under consideration for FY17 have been reviewed for scientific and technical merit by subject matter expert committees as well as for strategic alignment by the programmatic, scientific, and engineering leaders who are leading implementation of the LLNL's *Investment Strategy for Science, Technology, and Engineering*. The rigorous processes including call for proposals, concept paper development, assessment of strategic alignment, and scientific peer review ensured that the portfolio is of the highest quality and was highly aligned with the DOE, NNSA, and LLNL national security missions.

LLNL ensures its research is relevant, enables the national security missions, anticipates future needs and achieves world class scientific and technological improvements. Select accomplishments are described below:

- LLNL scientists created a method to analyze and detect fission chains that assess and evaluate nuclear material. The new methods are designed to exploit the burst timing pattern of neutrons and gamma rays emitted by fission chains in highly-enriched uranium (HEU) and plutonium.
- A study, published in *Nature Scientific Reports*, described a model developed by an LLNL-led team that predicted plutonium's magnetic behavior. This model resolved a conflict between theoretical predictions and observations about plutonium's (Pu) magnetism. Pu magnetic behavior is well predicted by LLNL developed first principal models. The ability to simulate the behavior of materials provides critical capability to perform stockpile stewardship missions.
- In January 2016, *Nature Physics* published an LLNL paper that described the first visualization of fast electron spatial energy deposition in a fast ignition target. This alternate to existing NIF processes allows optimizing target design by providing a more direct way to infer energy coupling in this pathway.
- American Nuclear Standards Society selected LLNL's Dr. Ron Basket from National Atmospheric Release Advisory Capability (NARAC) group, to coordinate the completion of two new national standards for modeling accidental releases from nuclear facilities.
- LLNL and LANL collaborators developed a process for drilling for radiological samples for laboratory analysis for verification of CTBTO test monitoring.
- LLNL scientists experimented with ablation front instability and capsule convergence ratio at NIF. New drive innovation designed for this mini-campaign produced significant improvements to implosion performance.
- NNSA Administrator presented awards to six LLNL scientists/engineers for support to CTBTO on site field exercises.
- Defense Ballistic Missile Analysis Committee met in March at LLNL to investigate future trends in the program and tour LLNL capabilities. Apex Gold gathered at LLNL to develop international terrorism nuclear response using capabilities in NARAC and forensic sciences to simulate a hypothetical nuclear scenario.
- A major simulation of underground nuclear explosions using 5,000 kilograms of TNT equivalent was conducted at Nevada site with LLNL performing a leading role in the experiment and high explosive formulation and operations. LLNL scientists also simulated signatures of gases from underground nuclear explosions using computer models of gas releases and tests detecting noble gas signals using advanced analytical equipment. Nuclear forensics garnered the cover article of February Analytical Chemistry describing characteristic signatures of residues from explosions and the process to narrow the range of potential origins.
- New research explores asteroid deflection by spacecraft kinetic impact in developing potential options to deflect planetary approaching objects modeling a large range of situations.
- Pu behavior reported in a July 2016 article in *Environmental Science and Technology* covers the range of Pu solubility's in the common iron mineral goethite to allow prediction of the transition from adsorption to precipitation for simulating transport behavior of Pu in contaminated environments.
- New carbon nanotube based dynamic, multifunctional nanoporous membrane fabric material that function like a second skin provide warfighters protections against biological and chemical warfare agents. The porosity of the protective wear change in response to detected agents.
- Improved additive manufacturing high fidelity 3D powder scale model to understand the physics of laser powder bed fusion of stainless steel and improve the quality of additive manufacturing

processes. The potential of unprecedented 3D printed architecture opens the pathway to super strong, ultra-lightweight and flexible materials for military and national security needs.

- Newly developed foam layered fuel capsules with internal ice layers are a new NIF experimental platform. This allows new world class experiments in high energy plasma research.

LLNL continues to perform research that is transformative, innovative, leading edge, high quality and advances the frontiers of science and engineering. New publications in high impact journals, (such as *Science* and *Nature*), and covers of those journals, demonstrate the world-class caliber of the work that push the frontiers of science in addition to the recognition that LLNL scientists and engineers are receiving in a broad array of technical fields. Referred journal publications in scientific literature are one measure of LLNL's productivity and LLNL published approximately 1,000 peer reviewed journal articles. Impact factors of the journals that published articles remains with average citations per paper at 22.1, which reflects the high degree which LLNL papers contribute to scientific dialogue across many fields.

- LLNL scientists and collaborators discovered elements 115, 117, and 118. That raises LLNL's total discoveries to six new element, including 113, 114, and 116. Each heavy element was detected in a short half-life with sophisticated separation and analytical techniques.
- As part of the international research team, LLNL scientists discovered five new atomic nuclei. The isotopes of uranium, neptunium, two of americium, and berkelium were detected using a new, fast and highly sensitive separation and detection system. These discoveries and technical innovations place LLNL in the top worldwide rank of heavy element research.
- In December 2015, *Science* published an LLNL article which described a newly discovered more efficient regime for generating soft x-rays with a table top ultraviolet laser. This high harmonic generation based technique provides a powerful new x-ray tool for basic research and technical applications.
- In December 2015, climate science at LLNL continued with recent groundbreaking publications in *Nature* with an analysis of model global precipitation estimates versus observations. A *Nature Climate Change* article in January 2016 addressed global ocean heat uptake in recent decades, and impacts in models and observations to improve understanding of the global distribution of energy fluxes.
- In December 2016, *Physical Review Letters* published an LLNL paper that described advanced materials development success in using electron beam chemical etching to form topographic patterns on the surface of diamonds. This innovation facilitates the nanofabrication of diamond for use in nanophotonics and quantum optics devices.
- High-Performance Computing (HPC) simulations of star formation were research highlights featured by NASA-supported LLNL staff in supercomputing developments where complex processes of gravity, supersonic turbulence, hydrodynamics, outflows, magnetic fields, chemistry and ionizing and non-ionizing radiation are combined in large scale simulations to model evolution of star formation.
- LLNL staff presented 24 papers at the fall American Geophysical Union meeting in December 2015 including the first discovery on an ancient tectonic plate in the mantle under the Indian Ocean published in *Science* 2015.
- Ultrafast x-ray "movie" identified, for the first time, biochemical interactions in perception of light by protein absorption of a photon. Published in May 2016 issue of *Science*, a high impact journal.
- A new bacterial phylum discovered by LLNL researchers investigating metagenomics data from the largest database ever analyzed exists in high temperature geothermal hot springs.

- First time discovery of carbon nanotube water transport by an order of magnitude. This validates, for the first time, a 200 year theory of the mechanism of proton transport and appeared in April 2016.
- Wind power studies improve turbine power utility scale wind farm simulation by comparing theoretical models to field observations of turbulence dynamics.
- LLNL research extended pressure density measurements for copper from 250 GPa up to a new world record of 450 GPa for use of research of materials at extreme conditions.
- LLNL developed additive manufacturing technologies for reactive and explosive materials to allow novel 3D printing of highly energetic compositions to control energy release rates in a manner not achievable in industrial practice. The article published in *Advanced Materials* describes the work.
- LLNL researchers developed the first ever biological identification method that uses information encoded in proteins of human hair. This groundbreaking technique can detect and identify markers in human hair more than 250 years old samples. It is a step change in forensic science which advances current state of the art based forensic hair identification.
- Yet another indication of how LLNL's work impacts various technical fields is when scientific publications choose to highlight LLNL articles. For example, *Discover* magazine selected a *Nature Geoscience* paper entitled "Impact Vaporization of Planetesimal Cores in the Late Stages of Planet Formation" as one of the Top 100 Scientific Stories of 2015. A paper in *Chemical Research in Toxicology* on tracing microdoses of carcinogens was chosen as one of the editors' "favorite articles." The *Scientist* magazine named a paper in *mSystems* describing a method that could improve taxon-specific measurements as its editor's choice publication in microbiology. The *Journal of Applied Physics* highlighted an LLNL paper as "noteworthy" for reporting on how point defect diffusion in commercial thin-film photovoltaic materials affects their performance. A paper published in the *AWS Journal* reporting effects of shielding gas on laser weld porosity in metal won the American Welding Society's McKay-Helm Award.

LLNL employed many strategies to maintain a healthy and vibrant research environment at LLNL. LLNL's LDRD program attract and retain world-class talent to maintain scientific collaborations with academia and other national laboratories. In FY 2016, LDRD has funded 102 postdocs of which 88 were funded at 10% or higher, 100 students of which 93 were funded at 10% or higher. These postdocs and students are the future of LLNL. LLNL's Workforce Development Initiatives (LWDI) named 15 LLNL scientists and engineers early in their careers to Livermore's first annual Early and Mid-Career Recognition (EMCR) Program, preformed annual competition for the prestigious Lawrence Postdoctoral Fellowship which attracted 155 applications. These are just 2 programs that the LWDI have preforms so far. LLNL also has implemented a Partnering and Educational Outreach program, received many awards, and had notable speakers talk at LLNL, which all help to maintain a healthy and vibrant research environment. LLNL continues to maintain a healthy and vibrant research environment at the LLNL and the community (see examples below).

- LLNL was named to the 2016 Forbes List of America's Best Large Employers, ranking No. 102 out of 500 employers that made the cut. Livermore is the only national laboratory on the list. This ranking places LLNL among the top 10 employers in the San Francisco Bay Area and among the top 12 in government services nationwide.
- LLNL and Georgetown University leaders gathered at the Livermore for a day of meetings in March to map out goals for the seven-year national laboratory/university collaboration. "The Georgetown visit

was a historic one for Livermore, not just because we hosted the Georgetown president and LLNL's senior team, but because this is the first time LLNL embarked on a joint strategic planning activity with a major university," says LLNL Director Bill Goldstein.

- LLNL heavily participated in the organization of the 38th annual Tri-Valley Expanding Your Horizons conference which had over 300 local girls, spanning grades six through nine, excited to learn about engineering. The goal of the conference, is to spark girls' interest in science, technology, engineering, and mathematics (STEM) in a fun environment. This year's theme, "#ilooklikeanengineer," celebrated engineering with the intention of building awareness of careers in engineering.
- LLNL's Ben Santer an Invited Speaker at the 66<sup>th</sup> Lindau Nobel Laureate Meeting: Every year 30-40 Nobel Laureates convene at Lindau, Germany to meet the next generation of leading scientists and young researchers from all over the world. Santer's talk was part of an interactive discussion about how scientists from various disciplines can collaborate to address the exciting climate insights that analysis of big data can offer, as well as the challenges associated with creating enormous volumes of data.
- LLNL Researcher Gives Keynote Presentation at Materials Conference: LLNL materials scientist Alexander Landa gave a keynote presentation at The Eighth International Conference on Materials Structure and Micromechanics of Fracture in Brno, Czech Republic, a leading venue for sharing research into the fundamental relations between structural and mechanical characteristics of materials. Landa's talk presented mathematical modeling on microstructure and deformation and described recent developments at Livermore in *ab initio* studies of refractory metals and their alloys.
- LLNL Nuclear Science Summer Program: A total of thirteen students have successfully completed LLNL's Nuclear Forensics Summer Program in early August. The eight-week summer internship is run through the Glenn T. Seaborg Institute in the Physical and Life Sciences Directorate. The goal of the program is to facilitate the training of the next generation of nuclear scientists and engineers to support national security in the field of nuclear forensics, as well as to strengthen the "pipeline" for scientific disciplines critical to DHS and DOE/NNSA.

LLNL made steady progress in the areas of technology transfer/partnerships and implementation of DOE's public access plan. A number of initiatives are being deployed, such as the National Laboratory Entrepreneur Academy and LabCorps to assist scientists in moving LLNL ideas, such as, promising clean energy into industry applications. The new CalCharge consortium is bringing together industry, academic, and DOE national laboratory representatives at LLNL to work on energy storage collaborations, while the new DOE High Performance Computing for Manufacturing program has funded \$5 million for work in the manufacturing technologies for clean energy. A key partnership agreement project, the High-Repetition-Rate Advanced Petawatt Laser System (HAPLS) hit an important milestone, achieving a target average energy level for the pump laser. Technology transfer success was recognized by awards from NASA Ames and from the Federal Laboratory Consortium Far West Region. To implement DOE's Public Access Plan, LLNL formed a public access committee and launched a web-based tool to enable identification of LLNL publications and prompting the author for submittal to OSTI. An issue was discovered in the labeling of publication information, which resulted in underrepresentation of accepted manuscripts; the issue has been since resolved. The percentage of submitted publications are expected to rise for the next reporting period. Below are few of accomplishments in FY16:

- LLNL executed 8 High Performance Computing Manufacturing Program (HPC4Mfg) Cooperative Research and Development Agreements (CRADAs). HPC4Mfg is a new Department of Energy initiative which will allow industry to leverage the high-performance computing capabilities of the national laboratories to advance clean energy manufacturing technologies.
- HAPLS hits another key milestone by completing the assembly and alignment of key subsystem of the HAPLS pump laser system. LLNL continues to win Research and Development (R&D) 100 awards. LLNL was awarded 3 R&D 100 awards, which now brings LLNL's total to 155 R&D 100 awards since 1978.
- LLNL was honored with the "Founder's Award" by the Innovation Tri-Valley Leadership Group (ITVLG). As a member of the ITVLG, LLNL participates in assisting ITVLG to form create initiatives and programs to bring in locally trained workforce, and to attract new businesses while helping existing businesses grow. LLNL's 3D-printing device, the Large Area Projection Micro Stereo-lithography (LAP $\mu$ SL) received the Federal Laboratory Consortium (FLC) far west region award for outstanding technology development. LAP $\mu$ SL produced parts can be used as master patterns for injection molding, thermoforming, blow molding and various metal-casting processes.
- LLNL doubled its submissions between the end of June and the end of August, and LLNL staff have demonstrated a commitment to improve LLNL's public access metrics and overall approach. LLNL planned earlier in the year to hold both metadata and full text Accepted Manuscripts (AMs) for 12 months before submission but has decided to replace this approach with a more efficient plan to transition from Harvesting as the submission method to OSTI to utilizing the AN 241.1 web service. LLNL will also begin to send the full text to the FTP directory prepared for that purpose. This will keep submissions and metrics current and the web service provides capability to provide additional metadata (such as ORCID IDs for authors) in each record. LLNL is also working to cross-reference existing systems (Information Management System (IMS) and the Science and Technology Achievements Tracking System (STATS)) to update publication information for LLNL authors, and has reached out to OSTI to work together in support of automated updates in the upcoming FY. Ongoing communications between LLNL and OSTI, combined with the rise in AM submissions over the year with the very noticeable uptick over the summer months indicate that LLNL has a solid plan for continued progress into FY17.
- The DOE's Office of Energy Efficiency and Renewable Energy Technology-to-Market Program (EERE TOMP) awarded LLNL and 2 partnering small business more than \$350,000 in Small Business Voucher (SBV) pilot funds for their expertise in advanced gas turbine manufacturing and geothermal engineering. EERE TOMP helps give small and mid-size businesses access to LLNL's resources, which helps improve industry awareness of national laboratory capabilities
- The Federal Laboratory Consortium (FLC) presented LLNL with an Outstanding Partnership Award for working with two start-up companies that successfully collaborated to demonstrate an environmentally sound geothermal silica extraction technology on a pilot scale. The FLC is chartered to promote, educate, and facilitate technology transfer among more than 300 federal laboratories, research centers, and agencies.

- LLNL scientists in the Computational Geosciences Group will collaborate with GreenFire Energy to assess the feasibility of dynamic stimulation, determining the appropriate energy release characteristics and the spatial and temporal distribution of detonations necessary to enable GreenFire's geothermal process. This collaborate is expected to develop a novel technology in which carbon dioxide is circulated through deep well bores to harvest geothermal energy.
- LLNL will match DOE's \$150,000 Technology Commercialization Fund with LLNL's own Industrial Partnerships Office Innovation Development Fund which will go toward engineering design, testing and evaluation of materials, and readying prototypes to attract private industry. These funds are for the Fire and Water Resistant Pre-filter, a ceramic pre-filter system concept to help protect HEPA (high-efficiency particulate air) filters in radiological facilities from damage.

LLNL demonstrated that institutional investments, including LDRD, produced high-impact, innovative R&D results and capabilities that are well aligned with Laboratory missions. In a paper, published in the June 15th edition of *Nature Communications*, LLNL LDRD researchers reported results obtained by embedding a catalytic enzyme in a polymer matrix to create the first reactor that can continuously produce methanol from methane at room temperature and pressure. In their approach, methane monooxygenase (MMO), an enzyme extracted from methane-metabolizing bacteria called methanotrophs, is embedded in a silicone lattice to create mechanically robust, gas-permeable membranes. Direct printing produces micron-scale structures with controlled geometry. The printed enzyme-embedded polymer motif is highly flexible, making it suitable for multiple future applications.

In the July 27 edition of *Advanced Materials* the research team reported, for the first time, that when a concentration gradient is used as a driving force, CNT nanochannels exhibit gas-transport rates exceeding predictions of a well-known diffusion theory by more than one order of magnitude. With Dengue virus in aqueous solutions as the test system, the team demonstrated the LLNL-developed CNT membranes provide effective protection from biological threats by size exclusion rather than by merely preventing surface wetting. The work was supported by LDRD program and DOD's DTRA C/B program. In a research published in *Nature Materials*, LLNL LDRD engineers demonstrated hierarchical metamaterials with disparate three-dimensional features spanning seven orders of magnitude, from nanometers to centimeters. At the macroscale the metamaterials exhibit high tensile elasticity (>20%) not found in their brittle-like metallic constituents, and a near-constant specific strength. Creation of these materials is enabled by a high-resolution, large-area additive manufacturing technique with scalability not achievable by conventional two-photon polymerization or traditional stereolithography. With overall part sizes approaching tens of centimeters, these unique nanostructured metamaterials could find use in a broad array of applications.



**Goal 5: Operations and Infrastructure, Allocated Fee 25%**

Operations and Infrastructure was rated as Good. LLNL excelled at maintaining and integrating an enterprise-wide focus and although it exceeded many expectations in effectively and efficiently managing the operations of the Laboratory, it experienced challenges in the area of security incident management. Because of these challenges, LLNL was unable to exceed overall expectations in safeguards and security, which is a critical functional area. LLNL exceeded expectations in the areas of cybersecurity. LLNL achieved an excellent record of safety for the year and exceeded expectations in delivering effective ES&H management, including in the areas of worker safety and health, environmental protection, occupational medicine, nuclear operations, radiation protection, and emergency management. LLNL continued to implement long-term work planning and control improvements to ensure safe work execution, but continued to be challenged by the need for additional resources and funding to achieve successful implementation of the new process. While LLNL provided new strategies and investments to achieve superior facility management results and has become NNSA's "go to" Site for many critical infrastructure initiatives, long-term challenges still remain in deferred maintenance and work order backlogs, especially at Site 300. LLNL continued to deliver efficient and effective business systems, producing excellent personal property inventory results, leading numerous complex and high dollar value acquisitions on behalf of the enterprise and provided outstanding legal management. It is noted the OIG's report on the Laser Inertial Fusion Energy (LIFE) Endeavor disclosed internal control weaknesses and significant questioned costs that were considered in our evaluation and further addressed in both Goals 5 and 6. LLNL delivered highly effective, efficient, and responsive environment, safety, health and quality (ESH&Q) management and processes. Performance accomplishments and achievements by select program are set forth below:

**Worker Safety and Health:** LLNL injury and illness rates continued their sustained downward trend and are at near historic lows. LLNL received two National Safety Council awards: 1) Million Work Hours Award: 3,000,000 employee hours worked without an occupational injury or illness involving days away from work, and 2) Occupational Excellence Achievement Award. LLNL successfully achieved external audit team's recommendation to continue both 18001 and 14001 certifications; the auditors identified an extraordinary thirty-four noteworthy practices. Examples include achieving an excellent safety record at the B654 construction site, recycling efforts in the Respirator Shop, use of color indicators to reflect task performance intervals for glove box operations, and development of ergonomically-designed work carts for the radio-frequency identification (RFID) project.

Safety culture improvement initiatives included successfully piloting the new survey tool, broadening the Safety Culture Sustainment Plan to include Security considerations and additional monitoring data, and a proactive communications campaign. These initiatives demonstrate a very robust institutional commitment to safety.

Under Industrial Safety, LLNL exceeded stated goals for Total Recordable Cases, Days Away Restricted Transfer, Days Away Cases, Electrical Severity Rate, and Pressure Relief Device inspections. LLNL completed assessments in construction safety, cranes, hoisting and rigging, fall protection, and a machine guarding independent internal assessments. However, there were three recordable electrical shocks of low severity.

The Industrial Hygiene (IH) Program partnered with the Occupational Medicine division on the improvements to the hearing conservation program, sponsored numerous chemical safety webinars for continued education opportunities, and exceeded all key metrics in the areas of sample reporting and turn-around times. All of the IH reviews for the facility assessments were completed within the 30 day goal. The IH Program successfully completed many assessments including nanomaterial safety, biosafety, chemical hygiene, respiratory protection, heat stress, and beryllium safety. The IH Risk Assessment Control database enhancements were a significant contributor to LLNL Worker Safety and Health Program's receiving of two National Safety Council awards. LLNL's historic low injury and illness rate is a result of the hazard analyses and controls implemented by the WS&H SME's including the Industrial Hygienists. The IH staff contributed greatly to the successful conversion and upgrade of the ChemTrack chemical inventory system to RFID, which is on schedule and expected to be completed second quarter of FY2017. Enabling safer and more efficient tracking of hazardous materials, the conversion effort has also resulted in the removal of over 10,500 unneeded chemicals for disposition, including approximately 1,000 gallons of paint diverted from landfill to recycling in a well-coordinated campaign that reduces safety risk and ongoing carrying costs for maintaining the inventory.

LLNL streamlined and improved institutional ES&H training resulting in an estimated seat-time savings of over 3,200 hours (\$197.6K) in FY2016; cumulative training improvements and cost-savings over the past four years are nearing an estimated 15,400 hours and \$1M. Several major courses were successfully revamped this year including Confined Space Entry, Confined Space Instruments, Machine and Equipment Safety, Radiation Generating Devices, Hexavalent Chromium Awareness, Ergonomics - Adjusting Your Workstation, and Lock Out and Tag, Fall Protection

The LLNL laser safety program continued to issue the Laser Lessons Learned newsletter for international distribution. LLNL completed 34 inspections of operations involving Class 3B/4 lasers. LLNL assisted with a technical design safety review for a high energy laser system at NASA/Ames Research Center. LLNL developed a revised Laser Safety course for laser workers that is available both internally and on the DOE On-line Training Center. The redevelopment of this course earned an EFCOG award. Although LLNL recently experienced 3 laser safety incidents, none of which resulted in injury, LLNL is currently reviewing its Laser Safety Program to ensure that new laser safety and operations personnel are not at risk for additional laser safety incidents.

LLNL led and contributed to two improvements to the DOE STD 1212 Explosives Safety Standard that will have wide impacts in the DOE enterprise including major benefits to the stockpile: 1) redefine and improve the Qualification and Testing standards of Insensitive High Explosives, which includes the challenging task of a multi-year collaboration with international experts, DOE leadership and DOE sites; and, 2) rewrite and improve the Electrical Equipment Sections. LLNL also completed a high profile experiment (SPE-5); however, HEAF had an off-normal event where an unintended initiation of an experiment occurred in the 1 kilogram shot tank.

LLNL's Biosafety Program experienced no significant findings resulting from more than 50 individual laboratory inspections and pathogens accountability inventory reviews (including all select agent laboratories). The program maintained full compliance with all applicable requirements including having spear-headed a comprehensive biological waste management assessment resulting in major changes to implementing documents and training. Based on two major external reviews/audits, one from the

Alameda County Medical Waste Department and the other from USDA/APHIS, the program successfully received its permits to operate or use controlled pathogens. The program responded proactively and comprehensively to CDC mandates associated with securing and dispositioning live select agents shipped from another federal agency laboratory and was not cited within a specific GAO audit final report associated with this national incident because of appropriate actions taken and having in place policies/SOPs to ensure pathogens inactivation validation. The program conducted its mandatory Select Agent facilities annual emergency exercise as required with programmatic success. The program also conducted its in-depth program review of its animal care and use program, including a full inspection of multiple facility laboratories with good results. The program continued to dedicate resources and time to continuous improvement activities including facility and equipment upgrades, the bolstering of rigor associated with training coursework, ensuring that implementing documents are reviewed and revised as needed and ensuring the inclusion of changes in federal requirements and guidelines are included and available on the new Biosafety website.

**Environmental Protection:** LLNL's environmental protection program continued to perform at a high level. LLNL maintained its ISO 14001 certification for the Environmental Management System (EMS). LLNL Environmental Functional Area (EFA) personnel effectively partnered with LFO in integrating assessments, performing inspections, and preparing reports including the Toxics Release Inventory (TRI) report, National Emission Standards for Hazardous Air Pollutants (NESHAPs) report, Annual Site Environmental Report (ASER), and the San Joaquin County Certified Unified Program Agency (CUPA) inspection. LLNL proactively performed internal assessments to increase awareness and ensure potential compliance issues are found and fixed. The Bay Area Air Quality Management District (BAAQMD) performed eight inspections during FY 2016 covering 107 air pollutant emission sources at Livermore Site (Site 200) and determined that all of the inspected sources were in full compliance with all BAAQMD rules and regulations. The San Joaquin Valley Air Pollution Control District (SJVAPCD) performed two inspections during FY 2016 covering 16 air pollutant emission sources at LLNL's Site 300 and determined that all Site 300 sources inspected were in compliance with all SJVAPCD rules and regulations. In response to recently implemented storm water monitoring regulations, LLNL staff successfully finalized industrial (as required to meet the CA state water board requirements) and municipal (voluntary) storm water sampling locations. LLNL successfully completed a major revision of its SPCC (Spill Prevention Control and Countermeasure) plan for Livermore Site and a consolidation of the SPCC plan for Site 300. LLNL also performed critical equipment upgrades at the Sewer Monitoring Complex, which is the compliance point for measuring liquid effluent discharges at Livermore Site; continuous, uninterrupted performance of monitoring equipment is necessary for compliance and for maintaining ongoing trust of the public and regulators.

LLNL's respirator shop located and implemented a recycling program that avoids landfilling waste respirators and significantly reduces laboratory costs related to replacement. LLNL partnered with Sandia (California) National Lab and with the City of Livermore, Bike East Bay, and the regional Wheels bus service to organize activities for the Bay Area Bike-to-Work Day. This promoted the benefits of cycling, including exercise and reduced fossil fuel use (reduced carbon footprint), and supports safe roads for bicyclists and motorists.

#### **Occupational Medicine:**

LLNL's Occupational Medicine (OM) functional area also continued to perform at a high level. One major

accomplishment was the completion of the upgrade to the Electronic Health Record (EHR). New enhancements now provide patient portal access, injury/illness notifications, work restriction reports, surveillance/certification compliance tracking, Beryllium registry report and a new scheduling features scheduled to be deployed in early FY 2017 that will enable subsequent retirement of two legacy systems. The Health Services Division (HSD) successfully obtained triennial Accreditation Association for Ambulatory Health Care (AAAHC) recertification with several noteworthy practices identified; the external reviewers commented "HSD is, in fact, recognized as a leading provider in this field (occupational medicine) has a well-written quality improvement and risk management plan and impressive travel medicine services (and with regard to occupational health) doing a stellar job." SD had a significant role in the new policy regarding mandatory audiogram testing for employees enrolled in the Hearing Conservation Program (HCP) which resulted in a significant increase in employee participation from less than 50% to approximately 78%. Additionally, OM partnered with EH&S Management and the Industrial Hygiene division to create a joint interdisciplinary HCP program case management team. This partnership supports integration, communication and more accurate OSHA and ORPS reporting. Prevention and wellness are areas in which HSD continued to excel and improve. LLNL won the distinction as this year's *Fittest DOE Lab in the Nation* due to significant employee participation (over one thousand) in the annual Get Active Program. The Working Well program also generated significant participation rates in the following programs: work station evaluation visits (819), early ergonomic intervention program visits (209), Musculoskeletal/Functional Movements Screens (249), and "1&done" biometric evaluations (664), Lighten Up (941), Health Coaching (181), Eating Well (42 teams), and the Early Ergonomic Intervention Program (EIP), which was cited in an ISO review (5-16) as a noteworthy practice, and had 342 visits. HSD also provided approximately 2800 flu vaccinations and collaborated with Pleasanton Kaiser to offer maintenance allergy injection services onsite to LLNL employees for both convenience and reduced travel time. And finally, the staff within HSD continued to earn very high satisfaction ratings (4.87/5, 97.4%) through the anonymous customer satisfaction surveys.

### **Nuclear Operations:**

LLNL did a superior job delivering effective and responsive nuclear operations through strong programs and knowledgeable/experienced facility managers and operations, engineering and technical support staff. Efficiencies have been gained across all nuclear operations programs by implementing a joint Master Assessment Plan/Master Assessment Schedule process that integrated assessment planning. LLNL demonstrated a significant effort in hiring additional staff to support nuclear operations and address attrition in areas such as safety analysis and cognizant system engineers. LLNL implemented a number of important safety basis and safety system changes including installation of a new Motor Control Center, switchover to a larger Fire Water Tank for fire suppression, completion of actions related to a legacy software code review, and significant revisions to the Waste Storage Facilities annual update. LLNL completed a significant deliverable in response to DOE Operating Experience Level 1, *Evaluation of Existing Facilities to DOE-STD-3009-2014*, evaluating the Plutonium Facility and Waste Storage Facilities DSAs against the requirements of DOE-STD-3009-2014. The nuclear facilities operated with very high availability to support the NNSA mission. LLNL completed a significant accomplishment with the closure of a B332 Plutonium Facility Justification for Continued Operations. This involved approval, modification, and implementation of important safety equipment and the recently approved B332 Documented Safety Analysis (DSA) and Technical Safety Requirement Annual Update, resulting in the removal of a significant vulnerability in Safety Class equipment. The DSA Annual Update deliverables have all been met and were submitted by the scheduled deadline. A number of amendments have been

submitted and approved by LFO; some quality issues were noted that required action. Overall, the safety basis activities demonstrated an effective process for ensuring adequate protection of the workers, the public and the environment.

LLNL's Nuclear Maintenance Management Program (NMMP) performed at a high level as LLNL provided exceptional availability of all safety structures, systems, and components that are part of the safety basis. Early in the year LFO and LLNL completed a joint assessment of the NMMP to determine full compliance with DOE O 433.1B; the program was found to be fully implemented. The most noteworthy accomplishment was the successful modification of the Preventative Maintenance Management System (PMMS) for greater flexibility, efficiency, and control in how the nuclear facility Task Code procedures are managed. LLNL worked to address recommendations from the Defense Nuclear Facility Safety Board (DNFSB) and DOE for improving Post Maintenance Testing and how critical spare parts are inventoried and stored. LLNL completed the development of a nuclear facility Post Maintenance Testing guide. Additionally, a process flow for the management of critical components was completed for vital safety systems and the Critical Spare Parts Inventory goals, which were developed during the year, are on track to be completed and implemented by December 31, 2016. LLNL has increased its participation in the EFCOG Engineering Practices Subgroup to establish connections to determine best practices across the complex.

LLNL demonstrated effective nuclear Conduct of Operations (ConOps) issuing its Nuclear Materials Technology Program (NMTP) ConOps Manual for nuclear facilities to document how operations are to be conducted and revising its Institutional ConOps Manual to incorporate updates to DOE Order 422.1, Conduct of Operations. As scheduled, LLNL completed ConOps assessments for NMTP nuclear facilities in the areas of Independent Verification, Communications, Control of Interrelated Processes and Control Area Activities; no significant issues were identified to indicate any adverse ConOps trends. LFO's assessment activities concluded that LLNL's assessments were planned and conducted appropriately to determine compliance with specific requirements and detailed attributes for each program element in DOE Order 422.1. Nuclear facility training and qualification remained effective with continued improvements in LLNL's training management (LTRAIN), training teams, and coordination with LFO on developing a risk-based, joint assessment schedule. LLNL conducted a thorough self-assessment of its training and qualification program, shadowed by LFO, which demonstrated an effective program with few areas for improvement.

The LLNL Readiness Program was executed at a high level and is well documented and effectively implemented. The Readiness Program provides clear communication with programmatic elements of LLNL with full participation from the Program, Nuclear Operations, and Safety Basis Division staff at the monthly Readiness Review Board meetings. Communication of the LLNL Readiness Program and Readiness SME with LFO has also been very effective. To facilitate a fuller understanding of inputs into and linkages to the Readiness Review process, RRB meeting agendas and minutes were expanded to reflect discussion of Major Modification Determinations and Implementation Verification Reviews. There was one Contractor RA conducted during the year using a full (non-checklist) approach. The RA review team demonstrated a high level of competence, technical knowledge, and independence. During the course of the period of review, a Defense Nuclear Safety Board staff-level review was conducted of the IVR process, which identified no findings or opportunities for improvement.

LLNL Criticality Safety demonstrated a high level of performance based on a comprehensive set of 15 performance metrics. LLNL experienced two minor and unrelated criticality safety infractions, neither of which met the reporting threshold for reporting to DOE. LLNL continued to achieve 100% compliance with training in the Fundamentals of Criticality Safety for workers in facilities with significant quantities of fissionable material. In support of Contractor Assurance, LLNL conducted its Triennial Internal Independent review of criticality safety, an assessment of the criticality safety training program for fissionable material workers. LLNL criticality safety engineers continued quarterly walk-through inspections of operations with significant quantities of fissionable material. In support of the stockpile, LLNL completed a comprehensive update to the W80 criticality safety statement. LLNL Criticality Safety Division played a key role in collaborative R&D work (with representatives from the UK) for emergency response detectors and nuclear accident dosimetry. LLNL also supported a Functional Area Management Review of Criticality Safety at Los Alamos National Laboratory.

The Packaging and Transportation Safety Program demonstrated a high level of performance, coordinating with stakeholders to update the LLNL Transportation Safety Manual. LLNL updated the 9978 Type B packaging procedures and completed personnel training in a timely manner to support JASPER contents shipped offsite. A noteworthy joint Management Self-Assessment performed with LFO was the review of the PATS' stakeholders' compliance with DOT 49 CFR 172.200 (document and records); excellent collaboration with the LFO was demonstrated during this review. Additionally, LLNL submitted the NNSA NA-531's Out-years Packaging Needs data call to LFO ahead of schedule.

**Radiation Protection:** LLNL's Radiation Protection program was executed at a high level, continuing to utilize assessments to identify opportunities to improve on existing practices and introduce new and more efficient work practices. The program also showed improvement through trending of measurable work activities as evidenced in the trending of instrument and sample analyses turn-around-times. There has been significant improvement in Radiation Generating Device tracking since the database was converted into an electronic format. The program successfully hosted a DOELAP on-site assessment of the External Dosimetry program. Unexpected events, including radioactive contamination events, turn-around-times for instrument calibration and sample analyses from the Radiological Measurement Laboratory and Bioassay Laboratory respectively continue to fall within acceptable low range. LLNL has continued deployment of the new TLD-based Area Monitoring Program, the results of which will be used to identify future opportunities to improve the cost-effectiveness of program implementation.

LLNL continued to make progress on developing and implementing the new work planning and control process, but did not achieve all of the goals. As assessed by LFO and supported by the recent parent company review, additional resources and funding are needed to achieve successful implementation of the new process. In FY16, LLNL began implementation of a pilot project at Site 300 with the new work control process and tool. This is a significant and positive step in the progress of site-wide implementation. LLNL is developing institutional documentation for the work control process. The work control tool continues to mature, training and certification efforts are noteworthy, and hiring of staff to support the process is starting to improve. Senior leadership involvement has been evident. LLNL was not able to perform new work under the revamped work planning process this fiscal year. It implemented nearly all elements at Site 300 but will not have Pre-Analyzed Tasks for explosives completed, which will lead to a delay of full implementation at Site 300 to early next fiscal year. LLNL continues establishing the new work control process at the main site with particular advancements at

NIF and with ES&H work. LLNL's documentation is progressing on schedule.

Overall, LLNL excelled in improving nuclear operations in completing the activities for the Building 332 Motor Control Center (MCC) Replacement Project and the TRU Waste Program packaging activities. The Building 332 MCC E410A3 Replacement Project is a complex multi-year project. When complete this project will rectify an electrical system vulnerability involving safety and non-safety electrical loads on the same MCC. For the MCC Project in FY 2016, LLNL successfully met all commitments. The critical lifts and installation/seismic securement were exceptionally well planned and executed. The project is a year behind baseline schedule due to a number of schedule impacts such as conflicts with higher priority work in the facility, limited availability of programmatic resources, and the need for redesign. A baseline change proposal is being prepared.

For the TRU Waste Program, LLNL safely completed packaging the metal oxidation residues and attractiveness level D material by the end of July well in advance of the FY commitment. This allowed LLNL the opportunity to package additional drums resulting in a significant reduction in risk. The metal oxidation residues and attractiveness level D material were loaded into Pipe Overpacks in accordance with DOE N 435.1 as required.

LLNL effectively supported capital projects including efforts to get the two line items, Expand Electrical Distribution System (EEDS) and Emergency Operations Center (EOC), off the ground. LLNL worked diligently with NA-50, NA-APM and the Field Office to come to consensus on the EEDS project's Acquisition Strategy path forward, which includes a contracting approach consistent with the Secretary's guidance on contracting incentives. LLNL fully supported the Analysis of Alternatives (AoA) process for the EOC project by hosting a site visit and providing tours, data, and presentations. This effort resulted in a thorough AoA that was determined to meet sufficiency requirements by the NNSA Office of Cost Estimating and Program Evaluation and satisfy all 22 GAO criteria. Additionally, LLNL completed the Mission Need Statement and Program Requirements Document for the new Utility Distribution System LI project ahead of schedule. LLNL completed a draft business case document, a draft lease agreement, and a draft real estate agreement for the HPCIC project and submitted the documents for HQ review and approval. LLNL has been responsive to questions and has supported several informational VTCs with interested parties. It continues to engage HQ reviewers in order to answer questions and move the project to the next step.

LLNL did not consistently deliver effective, efficient, and responsive security performance throughout the year. While the security organization maintained acceptable security through much of the year, there were several significant lapses in security performance and LLNL required corrective actions to correct issues with compliance and performance. These lapses are of significant concern to both LFO and HQ and will be closely monitored during FY 2017. One of the lapses involving access control revealed some fundamental flaws in security planning; LLNL's initial response was both slow and lacked appropriate management concern. On a positive note, LLNL participated in working groups, peer reviews, and in the review and comment process for new and revised DOE Directives and NNSA Supplemental Directives. Additionally, LLNL's Security Department was commended for its excellent security operations in support of Apex Gold, a ministerial level gathering attended by the DOE Secretary and several other dignitaries. This endeavor required months of planning and coordination with local, state, and federal law enforcement agencies and was accomplished without incident.



There were also instances where LLNL did not deliver effective, efficient, and responsive security performance in security incident management. As an Institution, LLNL experienced an increase in the number and severity of security incidents throughout FY 2016, several of which involved the protection of classified matter and access control. As noted in previous reports, LFO and NNSA are concerned with this trend and therefore have been closely monitoring these incidents. Significant NNSA Leadership attention was brought to light with respect to the access control incidents. Additionally, two of these incidents were significant enough to draw the attention of DOE's Office of Enforcement, which resulted in an onsite fact-finding investigation of the conditions that represented potentially serious violations of classified information security regulations. The circumstances behind these incidents have the potential to jeopardize the protection of sensitive or classified matter or operations if permitted to continue. As a result, LLNL is expected to perform the necessary causal analysis, immediately effectuate corrective actions to minimize recurrence of these types of incidents, and provide immediate notification of these incidents after they occur in accordance with the security matrix, approved policies and procedures, and Contract requirements, including applicable Orders. While these incidents did not significantly impact operations, the results could have been much different. The corrective actions for these security incidents as well as the number and severity of future security incidents will be closely monitored by LFO and NNSA. Additionally, the FY 2017 Performance and Evaluation Measurement Plan contains a Key Outcome in Goal 6 for LLNL Leadership to reduce the potential for security incidents across LLNL by implementing an integrated approach to enhance security culture through personal accountability, critical thinking and continuous improvement activities.

LLNL effectively managed its FY 2016 Institutional Assessment Plan achieving 100 percent on-time completion of 32 scheduled security self-assessments in each of the topical areas. In addition, LLNL completed over 40 unscheduled self-assessments of various security operations – these self-assessments were completed by various Security Management personnel. As a result of these self-assessments, LLNL self-identified deficiencies and initiated the necessary corrective actions and effectiveness reviews. LLNL is tracking the deficiencies to closure in the Institution's Issues Tracking System. LLNL consistently reported accurate results of its security self-assessment program to LFO in its QARs, thus enabling transparency and allowing LFO to successfully monitor the status of the security program. LLNL rated all of its topical areas as Satisfactory (highest rating achievable) and LFO concurs with these ratings.

LLNL successfully implemented the PEC regarding the modernization, revitalization, and recapitalization of Physical Security Infrastructure such as Kiosk design-build and procurement; enhancement of the Multiple Integrated Laser Engagement System – Handguns; Argus Ethernet and fiber network upgrades; and perimeter camera coverage augmentation. LLNL also implemented the PEC regarding the sustainment of personnel and critical skills by completing compliant training; sharing of best practices, and benchmarking with other NNSA sites; conducting 16 integrated table-top exercises; providing legal refresher briefings to Protective Force personnel and managers; achieving a 3-year site certification for Basic Security Police Officer Training – saving NNSA approximately \$494,000 for a 7-week offsite BSPOT training event; and participating in an LFO sponsored special security program review. LLNL also implemented the PEC to sustain key staff by filling 28 of its 62 vacancies, and participating in NA-70 working groups and DOE sponsored training activities.

Results from LFO's Integrated Assessment Plan (IAP) assessments indicate effective and efficient security performance. LLNL implemented corrective actions to address line issues as well as three other findings

in the Safeguards and Security Information Management System (SSIMS). The Finding regarding security fence lines remains open in SSIMS while LFO performs its review but the other findings have been closed. It is noted that the fence line funding does not have a material adverse impact on mission or security risk.

In addition to LFO's IAP oversight assessments, LLNL's security program underwent several external evaluations during FY 2016. The evaluations were extensive and cross-cut all topical areas of LLNL's security program. The evaluations were made by agencies such as the National Information Security Oversight Office; the Department of Homeland Security on behalf of the Office of Management and Budget; the DOE's Office of Inspector General, Office of Enterprise Assessments (EA), and Office of Classification. LLNL also experienced extensive evaluation by NNSA's Office of the Chief DNS on several subject areas. Overall, final results from these external evaluations found LLNL's security program to be satisfactory with no major issues being identified. Some minor compliance and performance issues were identified and LLNL is taking the necessary corrective actions to resolve the concerns. The results of LFO's IAP oversight assessment activities coupled with the results of these external evaluations were indicative of effective and efficient security performance. The issues that were identified did not have a major impact on LLNL's security program or mission execution. As a result, LFO will rate all security topical areas as satisfactory (highest rating achievable) in LLNL's FY 2016 Safeguards and Security Periodic Survey.

LLNL excelled in upgrading its Unclassified Visitor Tracking System (VTS). All PEC to upgrade LLNL's antiquated VTS to a contemporary, robust system were completed. The system will be compliant with DOE requirements, integrated with other LLNL systems, easily maintainable, and will supply the required approved, changed, or terminated visits, and assignment information into the DOE Foreign Access Central Tracking System. LLNL and Los Alamos National Laboratory (LANL) are expected to implement this system. The upgraded system added:

- Workflow engine and approval functionality
- Required data entry fields, including the ability to differentiate between sites
- Enhanced user authentication, authorization, and roles
- Ability to include building numbers to visits using an external building application
- Editing capability of on-going visits and approval management
- Ability to export information electronically for outgoing visits; and
- QA testing and essential bug fixes.

Emergency Management program performance remained at a high level as all deliverables required by the LFO-approved Emergency Readiness Assurance Plan (ERAP) were completed on schedule. Notable ERAP deliverables included the LLNL Emergency Plan, Building 231 Complex Emergency Planning Hazards Assessment (EPHA), Composite Emergency Planning Zone, Hazards Survey, and execution of the FY 2016 Full-Participation Exercise (FPE) and two functional exercises at EPHA facilities (i.e., Waste Storage Facilities and Biological/Site 300). A corrective action plan to address issues identified during the FPE was completed and corrective actions are being implemented. LLNL completed its FY 2016 Performance Indicators Plan to measure the program's effectiveness in eight functional areas per the NA-40 Performance Indicator Program, achieving "green" performance in all indicators. Actions were completed to fill open positions in the emergency response organization (ERO) and support additional

testing for categorization/classification activities to improve performance in two metrics previously rated as “less than green.” Institutional support was provided to those facilities having EPHAs to complete and document their operational drill activities. The number of facilities having EPHAs declined in FY 2016 with the consolidation of four existing EPHAs, collocated with a single response organization, into a single document to achieve program efficiencies. LLNL expended considerable resources to support an Office of Emergency Management Assessments (EA-33) review in August/September that focused on performance and included Limited Scope Performance Testing on two days.

LLNL initiated activities to support improvement of emergency preparedness and response core capabilities, including actions to increase overall readiness and performance. This was accomplished through initiatives and associated actions to (1) develop and implement improved procedures used in the Emergency Operations Center (EOC) for response to emergency events that are simple and task-based instructions, (2) improve emergency response organization (ERO) performance via a project training plan that emphasized hands-on practice, including implementation of decision-maker tabletop drills, and (3) achieve more timely protective actions through use of “canned” emergency voice alarm scripts and greater use of mass notification systems. These initiatives provided mechanisms to practice new EOC protocols and emphasize improvement items to support an increased state of readiness. The Headquarters Watch Office was invited and participated in the FY 2016 Full-Scale Exercise, and further participation in drill/exercise events was integrated into the site’s Five-Year Drill and Exercise Plan.

LLNL exceeded expectations to maintain, operate, and modernize DOE/NNSA facilities, infrastructure, and equipment. LLNL makes an effort to communicate infrastructure-related information to Program Managers and Field Office staff as needed. The F&I Total Recordable Cases (TRC) is hovering around 3.0 and the Preventative Maintenance (PM)/Corrective Maintenance (CM) ratio was about 50/50, 10% shy of the PM/CM goal of 55/45. The PM completion rates continued to remain within the set goals, however, the Work Order (WO) backlog trend is still increasing. LLNL continued to experience a 100% mechanical utilities availability rate and the electric utilities Average Service Availability Index (ASAI) was exceeded for the Site 200 but not met for Site 300 for much of the period. LLNL redirected resources to Site 300 to address findings from a FY 2015 LLNL Incident Analysis, which pointed to a dysfunctional work environment within the Site 300 maintenance department. To alleviate the situation, LLNL continued to provide more resources to the facility maintenance group at Site 300, both in indirect funding, staffing, and engineering subcontract support. LLNL also funded approximately \$14.9M in maintenance reinvestment and replacement projects, of which \$3.1M was directed to improve Site 300 infrastructure (45% more than in FY15). LLNL met several corrective action plan schedules by addressing the 2015 LFO Deficiency for the management of roll-up doors, cryogenic systems, boilers, and emergency lighting. Although LLNL found institutional roadblocks to implementing the new computer maintenance management system (CMMS) Enterprise Asset Management (EAM), it committed resources to upgrade its existing WO system, which is compatible and integrated with the new LLNL Work Control System. Additionally, LLNL continued to make great strides in setting up a maintenance mobile work package program and provided support to NA-50 in its efforts to implement this technology at all Sites. LLNL successfully implemented the reporting of maintenance expenditures directly into G2. Actuals for real property maintenance is 2.01%, within the NNSA PMP goal of 2%-4% of Replacement Plant Value (RPV). LLNL demonstrated excellent tracking and awareness of its Deferred Maintenance (DM) based on its implementation of NA-50’s clarifying Deferred Maintenance (DM) guidelines. LLNL is ahead of its peers based on its ability to accurately calculate its updated DM based on the guidance provided. Lastly, LLNL

successfully completed the migration to the DOE corporate Condition Assessment Information System (CAIS).

LLNL safely and without incident completed the demolition of T8710 trailer in January under budget and ahead of schedule. LLNL has also performed well despite delays to start planned characterization activities on excess contaminated facilities. Regardless of the delays, the resulting information has been beneficial in aiding preparation of transfer to EM and support of the EM walk downs of the facilities. However, LLNL's accounting of the prior year funding provided for trailer disposition resulting in reporting delays that required additional funds for demolition activities.

LLNL developed an extensive Predictive Maintenance (Pd.M.) plan and completed several key work efforts, including completing its review of numerous PM Task Codes for improvement and application of Pd.M. principles and techniques. LLNL successfully worked with NA-50 to refine the Mission Dependency Index (MDI) for all NNSA facilities. LLNL also earned an NA-50 Excellence Award (LLNL MDI Implementation Team) for their contributions for the implementation of MDI as part of the FY16 NA-50 "Make It Happen List." LLNL partnered with NA-50 to replace the Ten-Year Site Plans (TYSP) with a long-range, enterprise wide plan called the Master Asset Plan (MAP), and helped to organize, plan, and pilot the concept of the Infrastructure Deep Dives. The MAP will integrate mission, infrastructure, funding, and geographic information and be available via the G2 module. As NA-52 instituted the "Deep Dive," a comprehensive look at each NNSA site's mission, its connection with other sites, and the infrastructure needs and gaps to complete the mission, NA-52 and LLNL worked closely to develop the structure and content of a Deep Dive. This process now serves as the model for the subsequent Deep Dives within the NNSA Enterprise. LLNL supported NNSA's goal to implement a more robust infrastructure planning process with the Master Asset Plan Deep Dives. LLNL provided positive contributions and aided NNSA's effort for an enterprise-wide, long-range infrastructure plan, enabling our ability to understand and communicate the risks of the state of our current infrastructure to stakeholders.

LLNL continues to play a critical leadership role in the new Cooling and Heating Asset Management Program (CHAMP), formerly the HVAC Asset Management Program. LLNL hosted a successful Industry Day in 2016 to discuss their vision and execution plans of CHAMP as many interested companies attended the one-day event. The draft contract and request for proposal (RFP) was developed throughout the year, working issues such as burden rates, labor agreements, firm fixed pricing, and conflict of interest. The draft contract and RFP were prepared, submitted to NNSA and approved; however, the completion of this S-1 level activity was delayed six months from March 2016 to September 2016 in part due to the complexity and risk of the program. The solicitation package is currently out to bid. LLNL hosted the BUILDER Phase III planning meeting, met Phase II and Phase III milestones on time, participated extensively in NNSA's development of a Functionality Module, successfully completed various pilot tests, and provided support to NA-50 and the other NNSA sites. LLNL continued to be a main contributor to the success of the BUILDER project and was selected by NA-50 to provide specific developments. A validation of BUILDER's data will include using protocol and equipment historical life cycle data developed by LLNL. Additionally, LLNL has continually been the NNSA Site to work directly with the U.S. Army Corp of Engineers Research Laboratory for improving the BUILDER software itself.

LLNL improved the timeliness and quality of its G2 data submissions. Although LLNL hit a small bump on financials, it recovered well. LLNL was proactive in aligning its funding and costs within the new NA-50

WBS elements, and was helpful in working through complex transactions. Despite progress, LLNL still has issues understanding how to use G2 and would benefit from taking advantage of the resources offered to improve its skill set.

In response to the state's severe drought, LLNL continued to implement a best management practice from last year by further reducing the irrigation of turf and expanding the area of reduced (or no) irrigation. LLNL initiated the construction of a small demonstration, drought-tolerant garden at one building (B551E&W). LLNL reduced potable water used for irrigation by 57% from 2013, but overall water use intensity increased by 7% (13 million gallons) during the summer months compared to 2015. LLNL reviewed the conceptual design for a water conservation measure related to the reuse of treated wastewater for cooling and recommended that an engineering feasibility study be conducted before proceeding. Related to DOE's renewable energy goal and implementation of a best practice, LLNL supported the 3.3 MW on-site solar project, which started operations in February. LLNL needs to complete the alternate connection to LGS-15 in advance of the FY17 maintenance period for LGS-19. LLNL continues to develop a space planning process to be implemented site-wide. LLNL developed an innovative exit strategy for use in a mission critical facility (B231). LLNL initiated the pilot use of the Move Management Software with full implementation within one to two years. Implementation is expected to increase space utilization and decreasing operating costs, while providing appropriate temporary space for its new employees and interns.

LLNL's energy use intensity has decreased by 1% (normalized for heating degree days) since October 2015, but there has been little progress towards the DOE energy intensity reduction goal. An increasing number of building electric use meters are not connected and maintenance and repair of the advanced electric metering system should be improved. Natural gas use increased during the summer months and coincidentally work orders for gas-fired boilers have increased during the same time period. LLNL reviewed the results of a Utility Energy Services Contract (UESC) Investment Grade Audit that included energy and water conservation measures for several buildings and recommended that DOE/NNSA not proceed with implementation of the energy measures through a UESC task order. In addition, LLNL needs to continue to make progress on its initiative to close and consolidate datacenters and meter core datacenters.

LLNL successfully delivered efficient and effective business operations, systems and financial management based on a number of significant accomplishments as well as high level performance against metrics. LLNL overcame a myriad of logistical challenges to provide critical services, facilities, and equipment in support of the highly successfully Apex Gold event, which was hosted by the Secretary of Energy. LLNL also led numerous complex and high dollar value acquisitions on behalf of the enterprise including Commodity Technology Systems-1 scalable units, FastForward2, PathForward and the Cooling & Heating Asset Management Program (CHAMP), successfully leveraging the buying power of the Department and NNSA. A DOE Procurement Evaluation & Re-engineering Team (PERT) review reported several purchasing system strengths as well as notable observations regarding leadership, tools, and innovation. Supply chain performance against metrics remained at a very high level based on the results of LLNL's self-assessments and its Procurement Objectives Matrix. LLNL exceeded its strategic sourcing goals in support of the NNSA Supply Chain Management (SCMC) initiative as well as its overall small business goal. LLNL completed 28 eSourcing events totaling \$69.3 million worth of spend and drove \$11.1 million worth of commodity agreement spend, realizing 8% savings. LLNL completed 4,500

eStores transactions, an increase of 7% over FY 2015, yielding \$14.8 million of strategic tool enabled savings to date. LLNL also reported strategic site savings of \$7.2 million or 4.7% versus the target of 4%.

In the area of human resources, LLNL demonstrated strong performance against established metrics and is expected to exceed expectations in all four of the HR performance measures. One significant accomplishment for the year was the Terminated Vested Lump Sum Buyout project. The project resulted in \$9.7 million dollar cost avoidance to the government's long term liability. LLNL partnered with NNSA and Sandia National Laboratory to achieve consistency and equity on geographic pay differentials and has played a significant role in evaluating situations where geographic differentials could be applied to critical skill and hard to fill positions. However, there were some data integrity issues relative to its annual Benefits Cost Study and it appears that LLNL benefit costs exceeded the DOE and contract threshold of 105%. LLNL needs to aggressively assess benefit costs on an ongoing basis and continuously pursue opportunities to reduce benefit costs without reducing the overall benefit provided to employees.

Under financial management, LLNL received an overall rating of "good" (highest possible rating) for the year from NA-MB on its Financial Performance Measures Report. Notably, LLNL participated in Funds Distribution System (FDS) 2.0 NNSA/Science Enhanced User Acceptance Testing and supported FDS 2.0 testers for project milestones. LLNL also supported DOE initiatives by participating in multiple financial integration and transparency efforts led by NNSA/NA-MB, National Defense Authorization Act Section 3128 Efforts, and DP/NA-14, Cost Improvement Initiative and Cost Estimating Group. LLNL is centralizing DOE direct funding into the Project Billing Financial Data portal to integrate Strategic Partnership Projects and direct funding into one location, improving efficiency of data access and visibility of funding information. However, NA-MB reported a "fail" rating related to weakness in LLNL's internal controls for disclosure and use of G&A funds. The Office of Inspector General report issued in July 2016 on Laser Inertial Fusion Energy Endeavor (LIFE) indicated LLNL may have inappropriately used \$23.3M in indirect funds by charging LIFE costs to G&A expense accounts. The issue of whether a Management & Operating contractor can charge R&D activities to indirect cost pools is currently under review by NNSA senior leadership. The Contracting Officer has not issued a determination that such costs are unallowable or that the LIFE activities identified by the OIG were in fact Independent R&D.

The NNSA Personal Property Branch performed an inventory validation based on LLNL's approved Protocol Document (Gauge Model), which reported the highest rating, earning 484 of 500 available points. LLNL was able to account for 99.91% of attractive assets, 99.76% of equipment inventory items, and 100% of precious metals and firearms. New requirements were successfully implemented in conference management and property management in an efficient and effective manner with minimum impact to programs. In close collaboration with LFO, NNSA ALBQ Property Office and the NNSA M&O Property Council, the impact of the new property order was significantly mitigated by using a risk based approach. Site sustainability initiatives by the Business Directorate included 100% compostable products at the on-site cafeterias, continued expansion of the personal electric vehicle charging program, and plans to add additional electric vehicles to the government vehicle fleet and evaluate the use of charging infrastructure that relies upon renewable energy, i.e. solar panels.

LLNL excelled in its management of legal risk and incorporation of best practices into its business activities. LLNL's Office of General Counsel (OGC) continued to maintain open and transparent communication with the NNSA Field Office and concurrently with the NNSA Office of General Counsel on

a variety of complex and novel legal challenges. These challenges include reaching final settlement and resolving remaining issues in NNSA's largest and most complex employment litigation, as well as a myriad of intellectual property questions. This candid and cooperative relationship also facilitated the resolution of difficult issues of all types, including allowable costs, employee retaliation claims, insurance and benefits, and alternate financing. LLNL successfully recovered a substantial amount of attorney's fees in intellectual property litigation it had been diligently pursuing over the course of several years. This was an exceptional effort on the part of LLNL's OGC and it showed commitment to the Government and the taxpayer. Additionally, the LLNL OGC implemented a new patent dashboard that pulls financial and patent performance information into one coordinated interface to improve management visibility and streamline reporting. In cooperation with NNSA OGC and the Livermore Field Office counsel staff, LLNL's OGC was instrumental in the planning and coordination of the highly successful annual NNSA GC Training event that was held onsite in Livermore this year.

Overall, LLNL delivered effective, efficient and responsive cyber security and information technology. LLNL met mission and operational requirements including overall cost, schedule, and technical performance requirements. LLNL's Cyber Security Program (CSP) provided a stable and responsive cyber operating environment, enabling successful mission execution. LLNL successfully implemented this Objective by meeting most, and exceeding some, of the expectations set through locally developed performance evaluation criteria (PEC). Some examples of PEC implementation included LLNL successfully managing the CSP in accordance with the approved Risk Management Framework (RMF); updating its *Common Controls Catalog* and several additional key elements of the RMF; completing risk assessments which led to some risk-based decisions and cyber operations improvement; leading the NNSA Archer collaboration effort; continued cyber security technical collaborations, and delivery of accurate and timely assurance reports and the cyber security AOP. LLNL also continued to provide useful metrics in support of cyber security goals, objectives, and implementation factors that were consistently reported to the NNSA Chief Information Officer. LLNL exceeded the expectations with respect to Multi-Factor Authentication (MFA) implementation in FY 2016 by going beyond OMB's MFA mandate. Substantial work in this space accomplished this seemingly insurmountable goal. Overall, the content of the deliverables received by LFO and results of LLNL's cyber security operations met NNSA and LFO expectations.

LLNL effectively managed its FY 2016 Institutional Assessment Plan achieving 100 percent on-time completion of its scheduled cyber security self-assessments and reported quarterly performance ratings to LFO. LLNL self-identified deficiencies and observations and initiated effective corrective actions. Results from LFO's Integrated Assessment Plan (IAP) oversight assessments indicate effective and efficient security performance with no Findings being issued. In a related assessment conducted early this fiscal year, LLNL scored 100 percent on a Command Cyber Readiness re-inspection. This re-inspection focused on LLNL's compliance with Department of Defense (DoD) requirements for connection to DOD's SIPRNet. LLNL is only the second NNSA site to receive a perfect score.

LLNL demonstrated significant leadership towards implementing public key infrastructure (PKI) authentication for Secret Restricted Data systems in accordance with NNSA PKI expectations. All PEC were successfully implemented. LLNL led the Nuclear Weapons Enterprise in many areas of this project. LLNL completed iSRD CSP Change Forms, received approval to implement the PKI trained and certified Trusted Agents (TA) for PKI token distribution, and distributed over 1,500 PKI card readers. LLNL



submitted the Standard Operating Procedure to the Information Assurance Response Center (IARC) to implement full operations, deployed PKI middleware, and tested PKI authentication to DOD Certificate Authority (CA) resulting in a successful end-to-end test from an LLNL desktop to the DoD CA. LLNL also completed the stretch goals of designing, building, and activating a Limited Area in the 4-HELP/LivIT facility, implementing the Classified Distribution Interconnect Network (CDIN) with the required LFO approval, implementing iRSI and iSRD diskless systems, and training and staffing 4-HELP to support PKI efforts. These high-level achievements enabled LLNL to be fully ready to deploy PKI tokens once delivered, and LLNL had a defined plan to deploy all LLNL PKI tokens in as few as 30 days. These plans were reviewed with the NNSA Project Lead and the IARC with the commitment to release all 1,500 PKI tokens to LLNL prior to any other sites based on LLNL's achievements and commitment. However, in late August, the NA-IM suspended further PKI action on classified networks due to required additional analysis

During FY 2016, LLNL's CSP was subject to several comprehensive evaluations by agencies such as NNSA's Office of the Chief Information Officer (NA-IM); DOE's Telecommunications Security Program (AU-1.2), the Nation's Information Security Oversight Office; and DOE's OIG. These evaluations were extensive and cross-cut the cyber domain and included Information Technology. Overall, final results from these external evaluations found LLNL's CSP to be satisfactory with no major issues being identified. Some minor compliance and performance issues were identified and LLNL is taking the necessary corrective actions to resolve the concerns. The results of LFO's IAP oversight assessment activities coupled with these results were indicative of effective, efficient, and responsive cyber security performance, which is also supported by the fact that there were no cyber security incidents in FY 2016 that resulted in negative impact on cyber operations or mission execution. The issues that were identified did not have a major impact on LLNL's CSP or mission execution. Also, LLNL's CSP has been working hard to prepare for an upcoming evaluation by DOE's Office of EA which is scheduled for late October 2016. As a result, LFO rates the cyber security topical area as satisfactory (highest rating achievable).

LLNL met all critical priority Information Technology Implementation Factors (IFs), and most, high, and medium low priority IFs. LLNL is making progress toward achieving the DOE/NNSA milestone of deployment of HSPD-12\MFA Logical Access. LLNL excelled in completing deployment of OMB and DOE mandated requirement for IF11, Implement DNSSEC.

**Goal 6: Leadership, Allocated Fee 10%**

Leadership was rated as Very Good as LLNL exceeded many expectations providing leadership in support of the direction of the DOE/NNSA mission, improving safety culture, the responsiveness of the Laboratory leadership team to issues and opportunities for continuous improvement internally and across the Enterprise, and parent company involvement/commitment to the overall success of the Laboratory and the Enterprise. LLNL demonstrated strategic leadership through its participation and key role in numerous enterprise initiatives, councils, working groups, and collaborations that addressed issues and led to performance improvements. LLNL Director Bill Goldstein served as Chairman of the National Laboratory Directors' Council (NLDC) since December 2015. The NLDC provides a coordinating and integrating function for common issues across all seventeen national laboratories. Changes in key personnel were well coordinated with DOE/NNSA leadership and LLNL provided a high level of transparency, communication, and customer focus, especially with respect to work performed by the NIF organization. Livermore improved the assurance system by better defining risks, establishing joint assessments with LFO to reduce the number of assessments with enhanced focus on potential issues. Of particular significance was the Apex Gold event, which LLNL hosted at the request of the Secretary on January 27 - 28, 2016. LLNL received the DOE Secretary's Honor Awards in recognition of its support during the Iranian negotiations, development of the Energy Quadrennial Technology Review, Laboratory Operations and NNSA infrastructure efforts, and support for addressing the radiological waste release at Waste Isolation Pilot Plant. However, there were several issues that were of significant concern to both LFO and NNSA HQ senior leadership.

As discussed in Goal 5, LLNL response to several significant security lapses was not timely and did not generate appropriate LLNL management attention. Despite an increase in the number and severity of security incidents as well as engagement by senior NNSA leadership, LLNL management has been slow to acknowledge these performance issues or take ownership; this is not indicative of a positive security culture. Improvements in personal accountability, critical thinking, and continuous improvement activities would enhance the Laboratory's security culture. Therefore, we have included a Key Outcome in the FY 2017 PEMP under Goal 6 and will closely monitor improvements in LLNL's security culture.

The Office of Inspector General report issued in July 2016 on Laser Inertial Fusion Energy Endeavor (LIFE) indicated LLNL may have inappropriately used \$23.3M in indirect funds by charging LIFE costs to G&A expense accounts. This report is in addition to the report issued by LLNL Internal Audit in 2014 that disclosed the use of indirect funds for questionable business development activities for LIFE as well as NNSA ICF funds for LIFE contrary to direction from the NNSA Program Manager. NNSA is in the process of making its cost allowability determinations; however, the findings damage the reputation of the Laboratory and parent company. It is apparent that there were serious management control breakdowns and that LLNL's priorities on LIFE were not aligned with those of NNSA. It is noted that the current LLNL leadership team has taken steps to implement the OIG's recommendations applicable to the Laboratory regarding revising its Cost Accounting Standards Disclosure Statement and improving its internal controls and has demonstrated a commitment to improve transparency and partnership.

LLNL defined a realistic vision for the Laboratory through its LLNL Multi-Year Performance Strategy, which provided an overview of the Laboratory's strategies, efforts, and priorities covering the FY 2016–

FY 2020 timeframe. LLNL's vision is influenced by extensive strategic discussions with DOE/NNSA as well as through LLNL participation in other national and international forums. LLNL hosted the Apex Gold event at the request of the Secretary on January 27 - 28, 2016, which was executed at a very high level. The event was sponsored by the Department of Energy and the Kingdom of the Netherlands Ministry of Foreign Affairs and was the first ever minister-level gathering to identify national and international actions to address a nuclear crisis. Ministers and senior delegates from 37 nations, along with representatives from the International Atomic Energy Agency, the European Union and the United Nations, attended the event. Apex Gold laid important ground work for the 2016 Nuclear Security Summit, which President Obama hosted in Washington, D.C. The commitment of LLNL senior leadership was fully evident as LLNL staff closely partnered with LFO and NNSA HQ and meticulously planned to ensure the success of the event. The LLNL team provided additional outstanding support including hosting bilateral talks and providing tours of the LLNL facilities featuring some of NNSA's world-class capabilities. The LLNL Director received the Director of the Year Award for fiscal year (FY) 2015 from the Department of Energy's Office of Small and Disadvantaged Business Utilization (OSDBU). Dr. Goldstein was honored for encouraging and promoting collaborations with small businesses at LLNL. In April, LLNL represented DOE in a series of Joint Comprehensive Plan of Action (JCPOA) technical expert meetings in Vienna. LLNL was identified as the senior technical expert in bilateral and multilateral discussions among the UN Security Council's members, Iran and IAEA. LLNL representative engaged directly on implementation of uranium production, gas centrifuge, and nuclear reactor issues. The Secretary of Energy gave DOE Secretary's Honor Awards to eight LLNL members of the team, including the director, recognizing exceptional technical support during the nuclear nonproliferation negotiations with Iran. As noted in the award "The rapid evaluation of technical options, supported by extensive analytical work, provided timely and key support to the negotiations that led to the signing of the Joint Comprehensive Plan of Action in Vienna."

Additional examples of participation in these forums included:

- Hosted the USAF Nuclear Enterprise Meeting January 6, 2016, which addressed the future of the nuclear deterrent at LLNL.
- Engaged the major Air Force Commands on technology needs. General Hyten, AF Space Command reviewed space security technologies at the Lab on January 7, 2016. General Carlisle, Air Combat Command discussed cutting edge Tactical Requirements on December 3, 2015.
- Conducted the second seminar on November 17, 2015 on cross-domain deterrence as part of the "Nuclear Crossroads" Initiative. Primary objective was to advance the thinking of key challenges in cross-domain deterrence.
- LLNL and LANL co-hosted the Strategic Weapons in the 21st Century Conference on January 21, 2016. Conference addressed deterrence strategies of Russia, China and regional challenges with implications for the U.S. deterrent and U.S. related capabilities.
- Supported the NNSA Office of Policy and NA-2 in developing the strategic planning process between NNSA senior management and the Laboratory Directors.
- LLNL and SNL-CA cohosted the Army's Strategic Studies Group (SSG). SSG is a diverse cohort of the leaders drawn from all military services and the private sector. SSG has been tasked to assist with seeing the future world beyond 2025. Focus was on strategic and operational concepts for land forces to prepare for the future.

LLNL continued to successfully utilize and evaluate the performance of the Management Assurance System (MAS) and provided the annual Contractor Assurance System (CAS) assurance letter to its corporate Board of Governors. LLNL completed all self-assessments in accordance with the Institutional Assessment Plan, managed identified issues in the Issues Tracking system (ITS), and conducted Management Performance Reviews in accordance with its contractor assurance processes and procedures. LLNL completed its three year ISO 9001 recertification. LLNL successfully executed the jointly developed LFO-LLNL assessment schedule (JMAS) for FY 2016 in all eight functional areas that were integrated in FY 2015. LLNL fully met the FY 2016 goal to develop Joint Master Assessment Plans (JMAPs) for the following functional areas: Environmental Protection, Nuclear Operations, Training, Cyber Security, and Safeguards & Security. Multi-year assessment schedules and joint master assessment plans were also created to allow for scheduling of the required and risk-based assessments. Many of the functional areas integrated also exceeded integrated assessment planning requirements by documenting the other assurance mechanisms, which are relied upon to assure the health of the functional area, thus providing increased transparency and insight into functional area assurance processes. The integrated assessment planning effort resulted in improved collaboration, communication, and transparency, which has led to a better LFO understanding of the LLNL management assurance processes and improved LFO oversight. LLNL also completed all modifications and testing of ITS, deploying the update to allow LFO to record self-assessments in the database. LLNL partnered with LFO to define an approach for developing Integrated Health of the Program (IHOP) assessments for functional areas. Lastly, LLNL completed six Functional Management Reviews assessing performance through the utilization of parent company experts in accordance with its FY 2016 Parent Oversight Plan including six Functional Management Reviews (FMRs), which have been completed. These included Cranes/Hosting/Rigging Safety, Subcontract Work Control, Banking, Computerized Maintenance Management System (CMMS), O&B Deployed Teams, and LLNL Site-wide Work Planning and Control.

LLNL excelled at developing, integrating, and implementing enterprise solutions within the DOE/NNSA complex. LLNL leadership developed strategies, initiatives, programs, and activities that promoted the creation of a diverse and inclusive workforce and work environment. As Chair of the National Laboratory Directors Council (NLDC), LLNL Director Bill Goldstein gave critical attention to a wide variety of policy issues impacting the national laboratories and served as a leader on diversity initiatives. LLNL demonstrated leadership in developing Lab Day on the Hill in October 2015 and continued to provide leadership in the following key efforts and initiatives:

- Leading the FASTForward 2 Program with seven participating laboratories and four companies to address extreme-scale supercomputing technologies.
- Continuing to serve as the lead lab to address complex-wide facility solutions included in the DOE Infrastructure initiative, Mission Dependency Index (MDI), Knowledge-Based Condition Assessment (BUILDER), and complex-wide HVAC Asset Management Program.
- Received three NA-50 Excellence Awards for piloting the implementation of Mission Dependency Index (MDI), developing BUILDER software applications for infrastructure life-cycle modeling, and for the High Risk Excess Facilities Tram developing approaches for managing legacy facilities at the lowest operating surveillance costs.
- Cliff Shang received a Secretary's Honor Award for his contributions to the Laboratory Operations Board (LOB) General Purpose Infrastructure Cross Committee.
- Providing lead role in managing DOE's "Big Ideas" Initiatives – Grid Modernization and Subsurface

### Engineering.

- Managing the CORAL collaboration between LLNL, Oakridge and Argonne, which will culminate in three pre-exascale HPC systems delivered in the 2017 timeframe.
- Teaming with LANL to successfully complete the pit reuse milestone. The laboratories evaluated capabilities that pertain to the primary performance aspect of weapon certification for the specific application of pit reuse designs.
- Hosting the first NA-50 site visit “Deep Dive” review of infrastructure requirements. LLNL explicitly demonstrated the relationship between Program deliverables and infrastructure needs and investments. The four-day review brainstormed approaches to address needs in ways that optimized the likelihood of federal support and success, and the restructure of the 10 Year F/I Site Plan requirements for the Complex.
- Eight LLNL employees including the director of LLNL Forensics Center also received Secretary’s Honor Awards for their work on the radiological waste release at WIPP. Their efforts included developing the collection protocols for acquiring samples from the mine and for evaluating potential energetic reactions that might have played a role in the release.

LLNL exhibited professional excellence through executing both its programmatic work as well as its operations at a very high level. 15 scientists and engineers were named by LLNL as recipients in the first annual Early and Mid-Career Recognition (EMCR) award program in January 2016. NNSA Presented the Defense Award of Excellence to 10 teams of LLNL researchers & engineers as well as one individual in December 2015. The Awards were given to the S-1 Long-Term Deterrence Study of Emerging Threats Team, High-Z Diffraction Team, E-MSAD Team, Additive Manufacturing Focused Experiment Team, Intermediate Range KEP Arena Test Team, Reuse Hydrotest Team, Direct-Ink Write Cushion Team, Deterministic Particle Transport Team, and LLNL Bluebook Team. Thomas McAbee was recognized for his significant contributions by enhancing the primary metrics suite as a tool for design assessment, which has become the gold standard. LLNL also conducted two tailored workshops to help post docs and new employees prepare to compete more effectively for research funding through the Lab-wide Laboratory Directed R&D program. Workshops covered the proposal cycle, evaluation criteria, budget tips, and a brief introduction to successful proposal writing. In addition, coaching is offered on preparing and presenting materials in front of evaluation committees. The content of the workshop and coaching session are also relevant for submitting external funding applications and improving their general presentation skills. The Laboratory Director also expanded the Laboratory’s commitment to college education and advanced degree programs for deserving employees by ensuring adequate funding is made available for all employees seeking assistance under the approved tuition program guidelines. LLNL was named to the 2016 Forbes list of America’s Best Large Employers, ranking No. 102 out of 500 employers that made the cut and the only national laboratory on the list. This ranking places LLNL among the top 10 employers in the San Francisco Bay Area and among the top 12 in government services nationwide. In order to accelerate the pace at which technology developed at the national laboratories impacts the economy, LLNL, UC Davis and SNL formed a partnership to develop entrepreneurial skills. The current focus is a boot camp-like program to teach employees of the national labs the skills necessary to commercial science and engineering innovations. In March more than 180 visitors, mostly minority boys and girls from school districts in the Bay Area, visited the laboratory as part of the White House’s “My Brother’s Keeper (MBK initiative). The program aims to address the opportunity gap faced by young people of color, connect them to mentors and instill a passion for science, technology, engineering, and mathematics. In May 2016 eight student-veterans graduated in the first academic class of the

Engineering Technology Program that included summer internships at the Laboratory for veteran/students as well as training in advanced manufacturing, biotechnology, lasers, and national security-related projects. The program is a partnership between LLNL, Las Positas College, the Alameda County Workforce Investment Board, and the nonprofit Growth Sector. The Deputy Director and Representative Swalwell were featured speakers at the graduation. This year, LLNL welcomed more than 900 student interns. The Student Internship Program allows students to engage in work-study employment opportunities in Science, Technology, Engineering and Mathematics (STEM) and administrative fields during the summer academic break and provides a pipeline for further employment by LLNL.